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# Data Quality Objectives for Remedial Response Activities Development Process

CDM Federal Programs Corp., Annandale, VA

Prepared for

Environmental Protection Agency, Washington, DC

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Superfund

# Data Quality Objectives for Remedial Response Activities

## Development Process

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16. ABSTRACT

The Compendium provides Superfund Remedial Project Managers (RPM), qulaity assurance officers, and State officials with a consolidated ready reference for all remedial field procedures at uncontrolled hazardous waste sites. It is also intended to contribute to improved consistency in field procedures among the ten EPA Regions.

17. KEY WORDS AND DOCUMENT ANALYSIS

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# DATA QUALITY OBJECTIVES
# FOR REMEDIAL RESPONSE ACTIVITIES

## Development Process

Prepared for:

Office of Emergency and Remedial Response
and
Office of Waste Programs Enforcement
Office of Solid Waste and Emergency Response

U.S. Environmental Protection Agency
Washington, DC 20460

Prepared by:

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March 1987

# NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

# PREFACE

This document, Data Quality Objectives For Remedial Activities (Development Process), guides the user through the process of developing data quality objectives (DQOs) for site-specific remedial activities. Remedial response activities include remedial investigations (RI), feasibility studies (FS), remedial design (RD), and remedial action (RA). This guidance manual should be used in conjunction with the Data Quality Objectives For Remedial Response Activities (Example Scenario - RI/FS Activities at a Site With Contaminated Soils And Ground Water) which provides an outline of how the DQO process is applied to a hypothetical site situation.

These guidance documents will be updated in the future to focus on quantification of DQO's and other statistical issues.

This is one of a series of guidance documents prepared in accordance with the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) final rule, published in the Federal Register November 20, 1985 and effective February 18, 1986. These guidance documents will be updated in the near future to be consistent with provisions of the Superfund Amendments and Reauthorization Act (SARA) and the new NCP. The guidance document series includes the following titles:

- Guidance on Remedial Investigations Under CERCLA (EPA 540/G-85/002)
- Guidance on Feasibility Studies Under CERCLA (EPA 540/G-85/003)
- Superfund Remedial Design and Remedial Action Guidance (OSWER Directive 9355.0-4A)
- Compendium of Field Operations Methods (planned June 1987)
- Superfund Public Health Evaluation Manual (OSWER Directive 9285.4-1)
- Superfund Exposure Assessment Manual (OSWER Directive 9285.5-1)

Collectively, these documents provide guidance for the development and performance of technically sound and cost-effective remedial response activities which will support the program goals of both the Office of Emergency and Remedial Response (OERR) and the Office of Waste Programs Enforcement (OWPE). These documents are also available for use by state agencies and private parties conducting remedial response activities to ensure consistency with the intent of CERCLA and SARA.

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# LIST OF ACRONYMS

| | |
|---|---|
| ARAR | Applicable or Relevant and Appropriate Requirements |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (Superfund) |
| CDC | Centers for Disease Control |
| CLP | Contract Laboratory Program |
| COE | U.S. Army Corps of Engineers |
| DQO | Data Quality Objective |
| EMSL-LV | Environmental Monitoring and Support Laboratory - Las Vegas |
| ESD | Environmental Services Division (of EPA) |
| FIT | Field Investigation Team |
| FS | Feasibility Study |
| GC/MS | Gas Chromatograph/Mass Spectrograph |
| HSL | Hazardous Substance List |
| MDL | Method Detection Limit |
| NBS | National Bureau of Standards |
| NCP | National Contingency Plan |
| NEIC | National Enforcement Investigation Center |
| NPL | National Priorities List |
| ORC | Office of Regional Counsel |
| PARCC | Precision, Accuracy, Representativeness, Completeness, Comparability |
| PRP | Potentially Responsible Party |
| QAMS | Quality Assurance Management Staff |
| QAPP | Quality Assurance Program Plan |
| QAPjP | Quality Assurance Project Plan |
| QA/QC | Quality Assurance/Quality Control |
| RA | Remedial Action |
| RAS | Routine Analytical Service |
| RD | Remedial Design |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| RPM | Remedial Project Manager |
| RSCC | Regional Sample Control Center |
| S&A | Sampling and Analysis |
| SARA | Superfund Amendments and Reauthorization Act of 1986 |
| SAS | Special Analytical Service |
| SMO | Sample Management Office |
| SRM | Standard Reference Material |
| TAC | Technical Advisory Committee |
| TAT | Technical Assistance Team |
| TIC | Tentatively Identified Compounds |
| TSCA | Toxic Substances Control Act |
| VOC | Volatile Organic Compounds |

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# 1.0 INTRODUCTION

Data quality objectives (DQOs) are qualitative and quantitative statements which specify the quality of the data required to support Agency decisions during remedial response activities. DQOs are determined based on the end uses of the data to be collected. For example, depending on the project phase, sufficient data may have to be collected to characterize the site, evaluate remedial alternatives, determine design criteria, or monitor site conditions and/or remedial action effectiveness. DQOs are applicable to all data collection activities, including those performed for preliminary assessments/site investigations (PA/SI), remedial investigations (RI), feasibility studies (FS), remedial design (RD), and remedial actions (RA). The level of detail and data quality needed will vary based on the intended use of the data. The variability of site characteristics makes it impossible to apply a generic set of DQOs to all CERCLA activities, however investigators are expected to take advantage of previous experience and data collected for similar sites.

DQOs are established prior to data collection and are not considered a separate deliverable. Rather, the DQO development process is integrated with the project planning process, and the results are incorporated into the sampling and analysis (S&A) plan, quality assurance project plan (QAPjP) and, in general terms, into the work plan for the site. The DQO process results in a well thought out sampling and analysis plan which details the chosen sampling and analysis option and statements of the confidence in decisions made during the remedial process. Confidence statements are possible through the application of statistical techniques to the data.

Data quality objectives should be specified for each data collection activity associated with a remedial response. The majority of these data collection activities take place during a remedial investigation (RI) but additional data needs may be identified during the feasibility study (FS), remedial design (RD), and remedial action (RA).

All investigation activities should be conducted and documented in a manner that ensures that sufficient data of known quality are collected to support sound decisions concerning remedial action selection. This applies to fund-lead, federal or state enforcement-lead, and potentially responsible party-lead projects.

## 1.1 PURPOSE

The purpose of this guidance document is to identify the framework and process by which DQOs are developed and the individuals responsible for development of DQOs. This document is intended to guide the user through the process of DQO development. Each site will have a unique history, data availability, and other factors. Therefore, a unique set of DQOs must be developed for each site.

This DQO guidance acts as a supplement to existing remedial program guidance by providing procedures for determining a quantifiable degree of certainty which can be used in making site-specific decisions. In actual practice to date, projects conducted under CERCLA have complied with the intent of the DQO process. DQOs have been incorporated as parts of sampling and analytical plans, quality assurance project plans or work plans. The purpose of this guidance is to provide a more formal approach to integration of DQO development with S&A plan development and to improve the overall quality and cost effectiveness of data collection and analysis activities.

This guidance focuses specifically on the DQO process. RI/FS activities (planning and implementation) are presented only as a framework for DQOs and as such are not fully developed in accordance with RI/FS guidance. Similarly, this document is not meant to be guidance on overall development of sampling and analysis plans, quality assurance project plans, or work plans. Future documents will emphasize statistical considerations in the DQO process.

## 1.2 DATA QUALITY OBJECTIVE POLICY BACKGROUND

Mr. Alvin Alm, then Deputy Administrator of the EPA, in his memorandum of May 24, 1984 to the Assistant Administrators (AAs), stated that one of the most important steps in assuring the quality of environmental data is development of DQOs. He requested active participation of the AAs in the development of DQOs during the stages in which policy and guidance is crucial, and asked for identification of significant ongoing environmental data collection activities. The Quality Assurance Management Staff (QAMS) issued guidance on development of DQOs in October 1984. A checklist for DQO review was then issued in a memorandum from Stan Blacker on April 3, 1985. Appendix D includes a comparison of this checklist with this DQO guidance document. Additional guidance on the development of DQOs, specifically related to Stages 1 and 2 of the process, was provided in a draft document issued by QAMS March 17, 1986.

The approach to developing and implementing DQOs for remedial response activities has been established by a DQO Task Force comprising technical personnel from EPA Headquarters (OERR and OWPE), Regions 1, 2, 3, 5, 6 and 7; and EPA remedial contractors. The methodology used by the DQO Task Force was to apply the guidance provided by QAMS to the remedial response process. The efforts of the Task Force included identifying the elements of the DQO process within existing planning documents and organizing them into a formal implementation approach. The DQO development process presented in this document is based on the best available information but may be revised as additional information becomes available.

## 1.3 FORMAT

This document includes the following sections:

| | |
|---|---|
| 1.0 | Introduction |
| 2.0 | DQO Development Process - the process for developing DQOs and how DQO development relates to the remedial response program. |
| 3.0 | RI/FS-DQO Stage 1 - identification and involvement of data users, development of a conceptual site model and definition of decision types that will be made during the RI/FS process. |
| 4.0 | RI/FS-DQO Stage 2 - determining data needs and uses, establishing criteria for decisions, and identifying and selecting analytical and sampling options. |
| 5.0 | RI/FS-DQO Stage 3 - assembling sampling and analytical components into an overall sampling design and documentation required for a sampling and analytical program. |
| 6.0 | Remedial Design - Reserved |
| 7.0 | Remedial Action - Reserved |
| Appendix A | Statistical Considerations - provides a description of some statistical approaches which may be applied during a remedial action program. |
| Appendix B | Analytical Considerations - describes the various options that are available for analyzing samples from uncontrolled hazardous waste sites. |
| Appendix C | Sampling Considerations - provides discussion of sampling rationale related to the DQO development process. |

Additional appendices to the DQO document provide information on the QAMs DQO checklist, established criteria for RI/FS activities, and CLP performance criteria.

Sections of this manual are applicable to specific components of the remedial response process. Sections 1 and 2 are applicable to all remedial response activities; Sections 3, 4 and 5 apply specifically to the RI/FS process. Sections 6 and 7 are forthcoming and will provide guidance for the application of DQOs to Remedial Design Activities (Section 6) and to Remedial Actions (Section 7).

A companion to this guidance is the Data Quality Objectives For Remedial Response Activities Example Scenario) (EPA 1987) which provides an example case study of implementation of the DQO process.

# 2.0 DATA QUALITY OBJECTIVE DEVELOPMENT PROCESS

Data quality objectives are identified during project scoping and development of sampling and analysis plans. DQOs are established to ensure that the data collected are sufficient and of adequate quality for their intended uses. Data collected and analyzed in conformance with the DQO process described in this document can be used in assessing the uncertainty[1] associated with decisions related to remedial response.

## 2.1 DQO STAGES

Data quality objectives are developed through a three-stage process, as illustrated in Figure 2-1. Although the three stages are discussed sequentially in this guidance document, they should be undertaken in an interactive and iterative manner, whereby all the DQO elements are continually reviewed and reevaluated. As such, the DQO process is integrated with development of the S&A plan and is revised as needed based upon the results of each data collection activity. This process is illustrated in the example document.

### 2.1.1 STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process defines the types of decisions which will be made regarding site remediation through identifying data users, evaluating available data, developing a conceptual model, and specifying objectives for the project. Available information is compiled and analyzed to develop a conceptual model of the site. This model describes suspected sources, contaminant pathways, and potential receptors. The model facilitates identification of decisions which must be made and deficiencies in the existing information. Stage 1 results in the specification of the decision making process and identification of why new data are needed.

### 2.1.2 STAGE 2 - IDENTIFY DATA USES/NEEDS

Stage 2 stipulates criteria for determining data adequacy. This stage involves specifying the data necessary to meet the objectives set in Stage 1. Stage 2 includes selection of the sampling approaches and the analytical options for the site, including evaluation of multiple-option approaches to effect more timely or cost-effective data collection and evaluation.

### 2.1.3 STAGE 3 - DESIGN DATA COLLECTION PROGRAM

Stage 3 results in the specification of the methods by which data of acceptable quality and quantity will be obtained to make decisions. This information is provided in documents such as the S&A plan, and is summarized in the work plan.

## 2.2 RI/FS PROCESS

### 2.2.1 GENERAL APPROACH

The overall objective of an RI/FS is to determine the nature and extent of the threat posed by the release of hazardous substances and to evaluate proposed remedies. The ultimate goal is to select a cost-effective remedial alternative which mitigates threats to and provides protection of public health, welfare, and the environment, consistent with the NCP.

---

[1] The term, uncertainty, is used as a catchall term to describe the likelihood of all types of errors associated with a particular decision. There is not a precise statistical definition of the term since the precise definition varies from decision to decision; however, it can be stated that uncertainty is always a function of the distribution of the statistics used in making the decision.

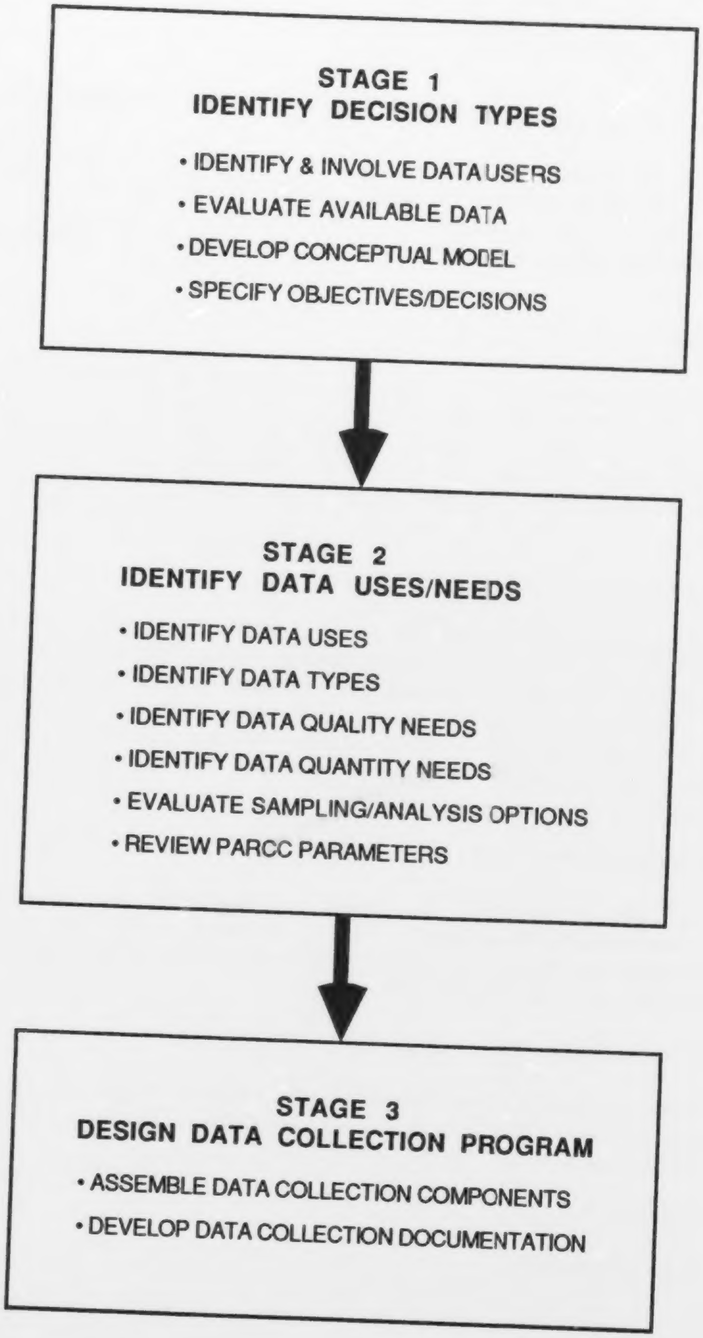
STAGE 1
IDENTIFY DECISION TYPES
• IDENTIFY & INVOLVE DATA USERS
• EVALUATE AVAILABLE DATA
• DEVELOP CONCEPTUAL MODEL
• SPECIFY OBJECTIVES/DECISIONS
STAGE 2
IDENTIFY DATA USES/NEEDS
• IDENTIFY DATA USES
• IDENTIFY DATA TYPES
• IDENTIFY DATA QUALITY NEEDS
• IDENTIFY DATA QUANTITY NEEDS
• EVALUATE SAMPLING/ANALYSIS OPTIONS
• REVIEW PARCC PARAMETERS
STAGE 3
DESIGN DATA COLLECTION PROGRAM
• ASSEMBLE DATA COLLECTION COMPONENTS
• DEVELOP DATA COLLECTION DOCUMENTATION

FIGURE 2-1
DQO THREE-STAGE PROCESS

RIs consist of data gathering activities undertaken to determine the degree and extent of contamination at a site. The data are used in the identification, screening, and evaluation of remedial alternatives. The objective of the RI is to collect the necessary data to determine the distribution and migration of contaminants; identify cleanup criteria; and identify and support the remedial alternative evaluation.

Feasibility studies entail development, screening, and evaluation of remedial alternatives. The objectives of the FS are to develop and evaluate the remedial action alternatives with respect to protection of public health and the environment, compliance with ARARs, and reduction of mobility and/or toxicity. In order to ensure that adequate and sufficient data are collected for performance of the FS, site managers must continually coordinate the evaluation and re-evaluation of data collected during the RI.

The RI/FS typically addresses data collection and site characterization from the perspective of contaminant source and contaminant migration pathways. Once pathways are established and human and environmental receptors are identified, further data collection efforts can be directed toward evaluating the potential impact upon receptors, and for use in evaluating potential remedial technologies and alternatives.

Through the process of developing DQOs, a series of statements and definitions of the types, quantity and quality of data required for specific uses will be developed.

### 2.2.2 PHASED RI/FS APPROACH

The amount and quality of data required to support selection of a remedial alternative will vary by site. In many situations it may not be possible to identify all data needs during the initial scoping activities. Rather, data needs will become more clearly defined as additional data are obtained and evaluated. By separating the remedial investigation into phases, data can be collected and evaluated sequentially, with a refinement or redefinition of data collection needs at the completion of each phase. Figure 2-2 illustrates the phased RI/FS approach.

It is seldom possible to identify fully all the data needed to complete an RI/FS at the outset of the scoping process. For complex sites, the phased approach provides more control of investigative activities than a singular sampling/analysis event. Applying the DQO process to a phased investigation improves the usability of the data and the cost effectiveness of the investigation.

## 2.3 REMEDIAL DESIGN

Following selection of a remedy (based on the RI/FS) and approval of the Record of Decision (ROD) or Enforcement Decision Document (EDD), design activities are initiated. Additional field data collection activities may be required during the remedial design phase to supplement the technical data available from the RI/FS.

Cost estimates should be refined to the +15/-10 percent range based on data collected during the RD (EPA 1986). The type of data required during the RD varies depending on the type of remedies. For soil excavation, a good estimate of contaminated soil volume is needed; for treatment options, a refined estimate of the physical/chemical waste character may be required. If the RI is carefully planned with accurate foresight of FS and RD data needs, sampling activities during the RD phase should be minimized. The practical application of DQOs to RD activities will be described in future updates to this document.

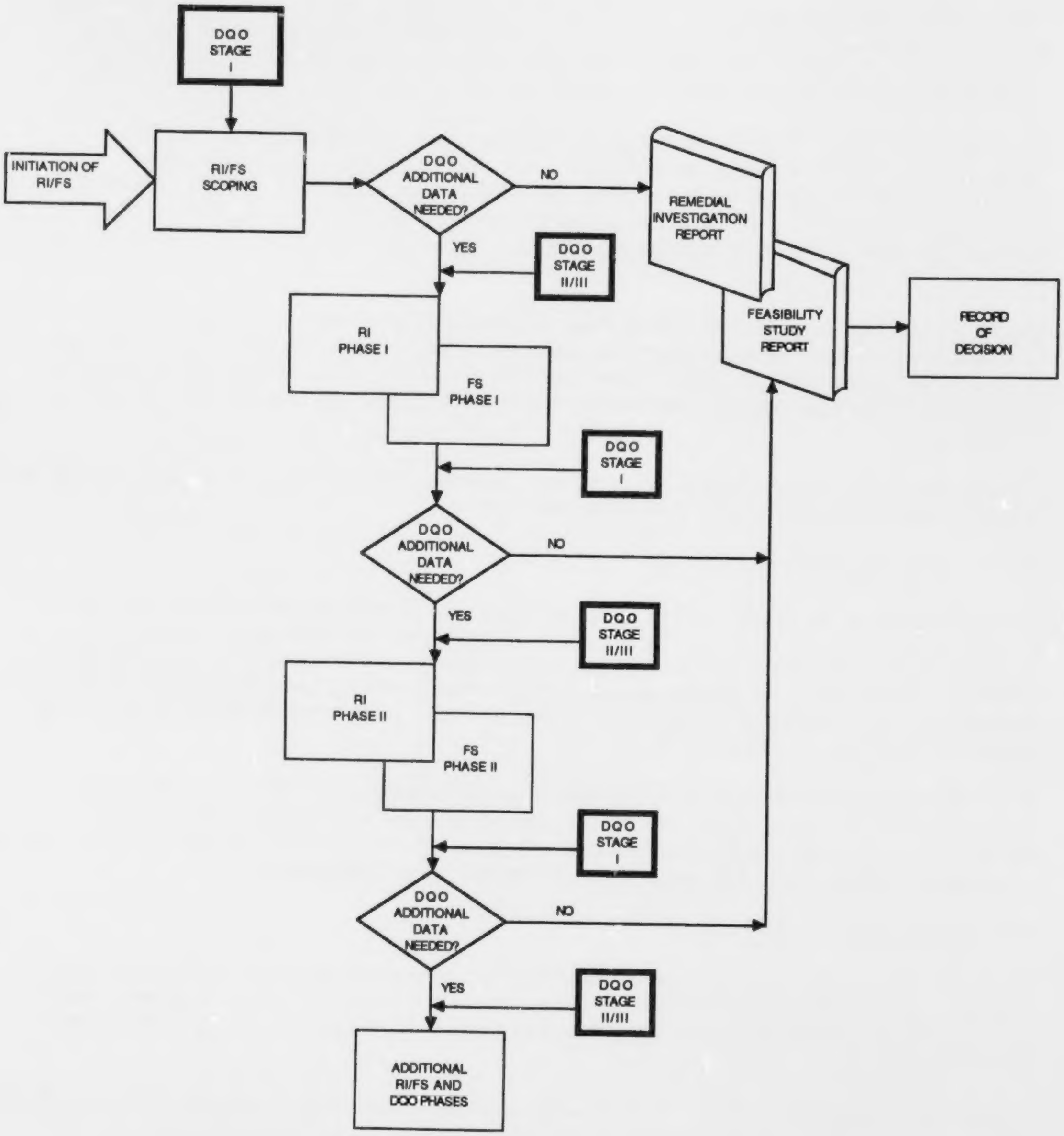
DQO STAGE I
INITIATION OF RI/FS
RI/FS SCOPING
DQO ADDITIONAL DATA NEEDED?
NO
REMEDIAL INVESTIGATION REPORT
YES
DQO STAGE II/III
FEASIBILITY STUDY REPORT
RECORD OF DECISION
RI PHASE I
FS PHASE I
DQO STAGE I
DQO ADDITIONAL DATA NEEDED?
NO
YES
DQO STAGE II/III
RI PHASE II
FS PHASE II
DQO STAGE I
DQO ADDITIONAL DATA NEEDED?
NO
YES
DQO STAGE II/III
ADDITIONAL RI/FS AND DQO PHASES

FIGURE 2-2
PHASED RI/FS APPROACH AND THE DQO PROCESS

## 2.4 REMEDIAL ACTION

RA activities entail the actual implementation of the alternative selected in the ROD/EDD. As with the RD, additional data collection activities may have to be conducted during the RA, and the DQO process utilized. Data collected during the RA are used to evaluate the progress of the RA and to verify that the set performance criteria were achieved.

## 2.5 DATA QUALITY OBJECTIVES DOCUMENTATION

The DQO development process is initiated during project scoping and is completed in conjunction with the development of an S&A plan for each project phase. The three stages of the DQO development process are interactive in nature. As additional details regarding the site are discovered, the decisions which will be made during the project are refined. This allows for further specification of data needs and for design of the data collection program.

As the DQO process continues, the scoping of the project will become refined. Additional decision types may be needed (Stage 1), or data collection activities may be modified (Stage 2 and Stage 3) based on evaluation of data (Stage 1).

Development of DQOs in a formal manner ensures that the appropriate data are obtained to meet the objectives of the RI/FS, RD or RA. Documentation of DQOs can be provided primarily in the S&A plan (which includes QAPjP elements), and summarized in the work plan.

## 2.6 REFERENCES

U.S. Environmental Protection Agency. 1985a. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, DC. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/002. June.

___. 1985b. Guidance on Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, DC. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/003. June.

___. 1986. Superfund Remedial Design and Remedial Action Guidance, Office of Emergency and Remedial Response. OSWER Directive 9355.0-4A. June.

## 3.0 RI/FS DQO STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process is undertaken to identify the individuals responsible for decisions, to identify and involve data users, and to define the types of decisions which will be made as part of each RI/FS. Decisions are made following evaluation of data at various points during the RI/FS. The general decision types are identified early in Stage 1 to ensure that an investigative approach which will yield data sufficient to support the decisions.

The major elements of Stage 1 include:

- Identifying and involving data users
- Evaluating available information
- Developing a conceptual model
- Specifing RI/FS objectives and decisions

Stage 1 of the DQO process is an inherent part of the project scoping process. The thought process by which a work plan is developed naturally encompasses the Stage 1 DQO elements. Figure 3-1 illustrates the Stage 1 elements. Although the elements of Stage 1 can be thought of as distinct steps, they are a continuous thought process.

### 3.1 IDENTIFY AND INVOLVE DATA USERS

DQO development requires involving the data users during planning of remedial activities. Because of the interdisciplinary nature of remedial activities, it is important that the appropriate technical expertise is identified and obtained for the DQO development process.

### 3.1.1 DECISION MAKER'S ROLE

The key RI/FS decision is remedy selection (i.e., ROD/EDD signature). For the majority of RI/FS projects, remedy selection is the responsibility of the Regional Administrator (RA). Program management responsibilities are delegated to the Waste Management Division Director and managers, with project specific management and oversight assigned to Remedial Project Managers (RPMs). Senior management staff are likely to be involved primarily in scoping of the RI/FS and review and approval of the decision document.

The EPA RPM is the designated decision maker for the DQO development process. In this role, the RPM is responsible for coordinating the DQO development process; and overseeing remedial contractors, state officials, or private parties conducting the RI/FS.

For federal lead projects, day-to-day decision making becomes the responsibility of the remedial contractor's site manager under the direction of the RPM. Remedial contractors incorporate technical review and oversight by senior level management and technical experts into their internal scoping and project planning process. For state lead or private party lead projects, the state project manager or private party project manager will be a key decision maker assisted by their contractor's site manager. The RPM should be in close contact with the federal remedial contractor, state project manager, or private party project manager to ensure that project activities are proceeding on track and are consistent with EPA policy and guidance.

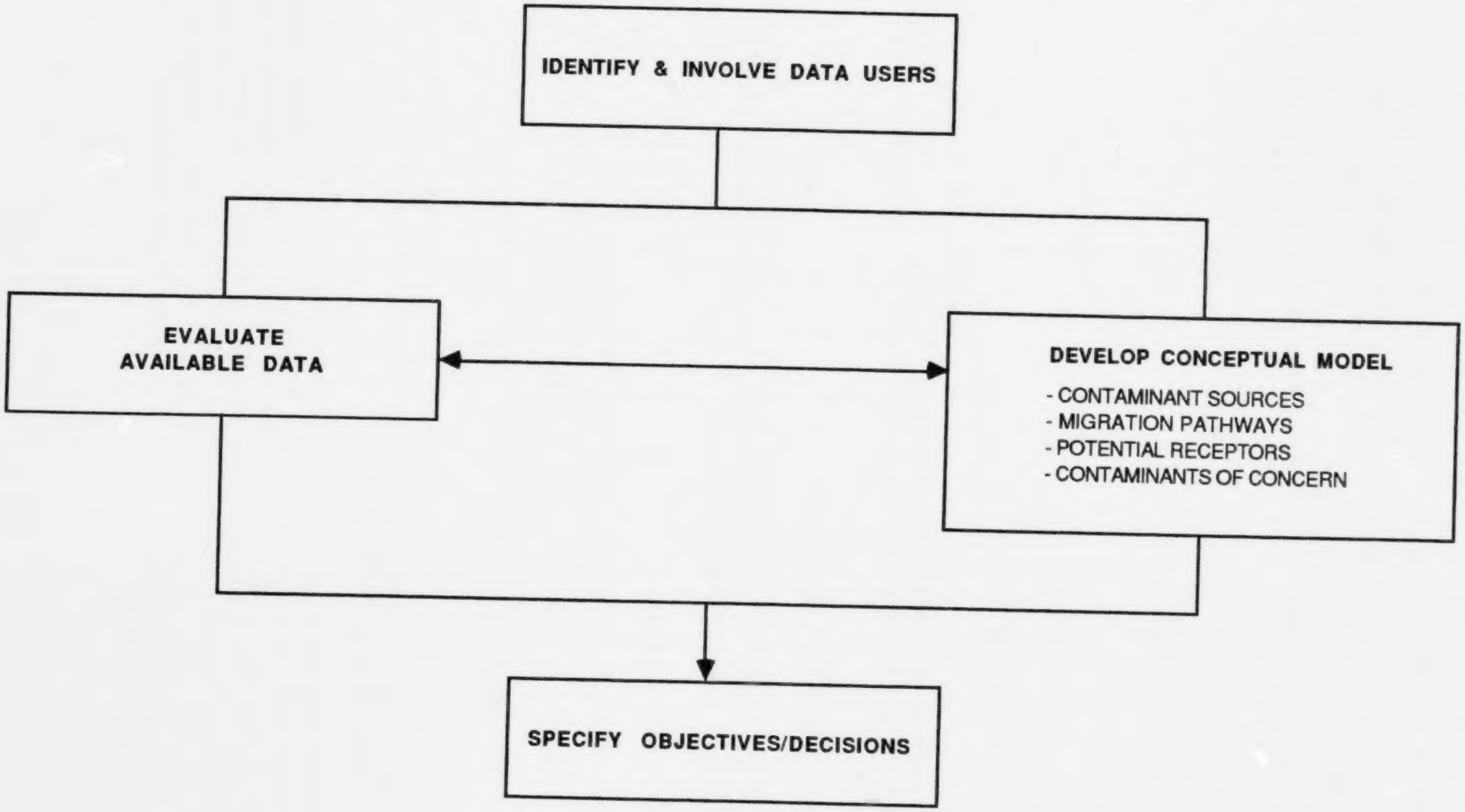
IDENTIFY & INVOLVE DATA USERS
EVALUATE AVAILABLE DATA
DEVELOP CONCEPTUAL MODEL
- CONTAMINANT SOURCES
- MIGRATION PATHWAYS
- POTENTIAL RECEPTORS
- CONTAMINANTS OF CONCERN
SPECIFY OBJECTIVES/DECISIONS

FIGURE 3-1
DQO STAGE 1 ELEMENTS

### 3.1.2 DATA USERS' ROLE

The interactions of decision makers and various data users during the DQO development process is illustrated in Figure 3-2 and discussed below.

#### Primary Data Users

Primary data users are those individuals involved in ongoing RI/FS activities. These activities include RI/FS planning and implementation, project management and oversight, site specific decision making, and DQO development. For federal lead projects, this includes the RPM and the remedial contractor's site manager and staff. For state lead or private party lead projects, this includes the state or private party manager and their contractor's site manager/staff, along with the RPM.

The contractor site manager must identify the appropriate contractor technical staff based upon the overall problems at the site. For example, if ground water contamination is a concern, geologists/hydrogeologists and water supply/treatment engineers may be involved, at a minimum. If surface water contamination is a concern, aquatic biologists, limnologists and water resource engineers may be involved. Analytical chemists can assist in specifying the types of analyses to be used and the limitations of the particular techniques or methods. Individuals familiar with the interactions of chemicals in the environment, such as geochemists, soil scientists, and chemists, must also be involved to assess environmental impacts. Geostatisticians can provide assistance in evaluating spatially distributed data. Toxicologists and individuals familiar with risk assessments should also be involved early in the scoping process to ensure that appropriate consideration is given to potential migration pathways, receptors and contaminants of concern.

#### Secondary Data Users

Secondary data users rely on RI/FS outputs to support their activities. Secondary data users provide input to the decision maker and primary data users by communicating generic or site specific data needs. Depending on project lead, secondary data users may include the state, enforcement personnel, ATSDR, U.S. Army Corps of Engineers, and others. The level of involvement of secondary data users will vary according to site specific requirements, program lead, or Agency policy.

#### Technical Support and Project Review/Audit

At the request of the RPM, technical specialists may provide support related to project specific sampling and analytical activities, regulatory requirements, etc. Project review and audit personnel such as ESD, Office of Regional Counsel, and EPA HQ help ensure QA program integrity and compliance with program policy.

## 3.2 EVALUATE AVAILABLE INFORMATION

Available information is reviewed and evaluated as the initial step in the RI/FS process. This review provides the foundation for additional on-site activities and serves as the database for RI/FS scoping. The review and an initial site visit are used for a preliminary interpretation of site conditions.

### 3.2.1 DESCRIBE CURRENT SITUATION

The initial data review should be as thorough and accurate as possible. Information should be obtained from EPA technical and enforcement files, state/local regulatory agency files, USGS files, and other relevant sources. Files from potentially responsible parties (PRPs) should also be referred to when available. A detailed list of potential data sources is contained in Section 2.0 of the Guidance for Remedial Investigations Under CERCLA (EPA 1985a).

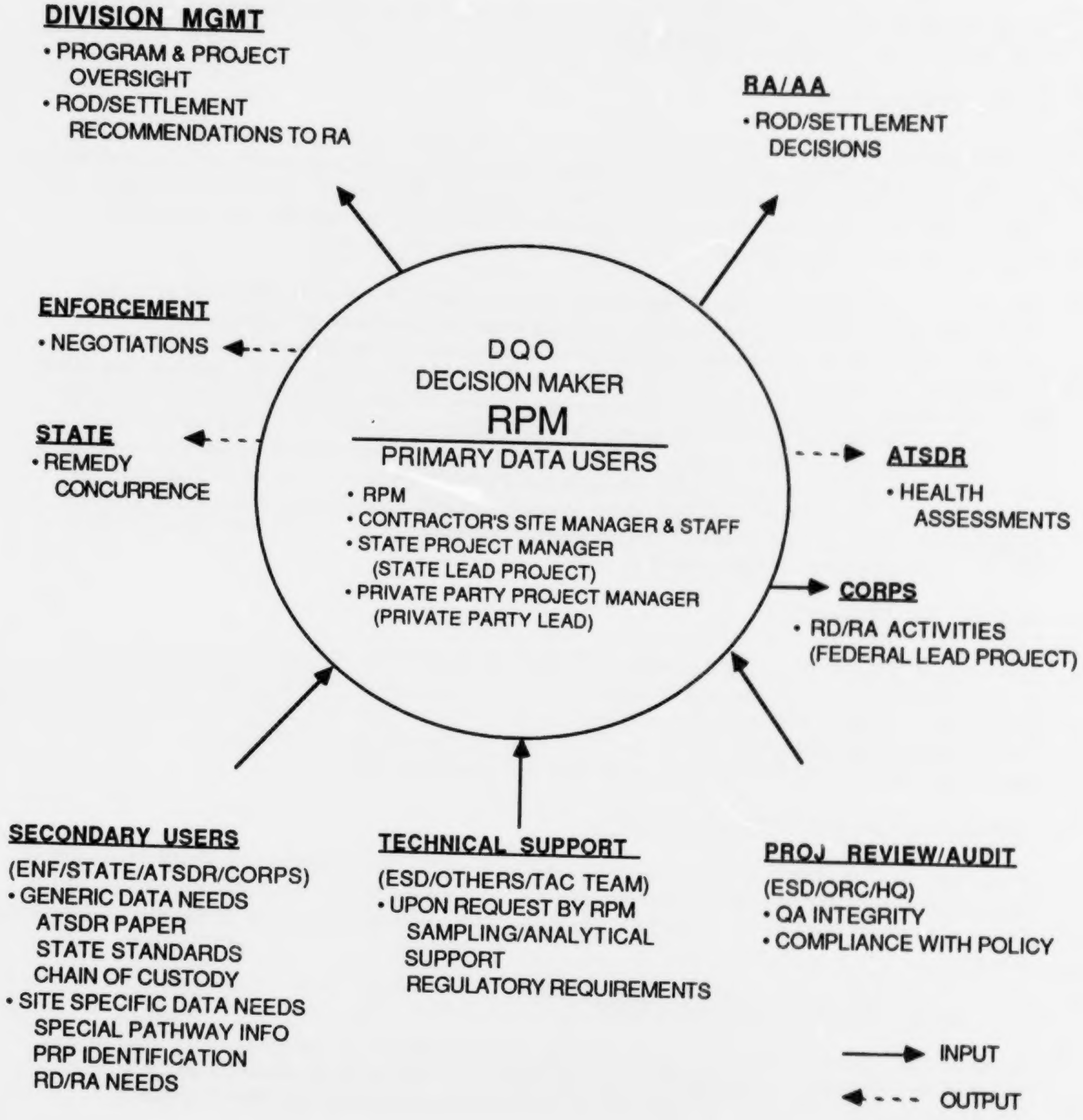
DIVISION MGMT
• PROGRAM & PROJECT OVERSIGHT
• ROD/SETTLEMENT RECOMMENDATIONS TO RA
RA/AA
• ROD/SETTLEMENT DECISIONS
ENFORCEMENT
• NEGOTIATIONS
STATE
• REMEDY CONCURRENCE
DQO
DECISION MAKER
RPM
PRIMARY DATA USERS
• RPM
• CONTRACTOR'S SITE MANAGER & STAFF
• STATE PROJECT MANAGER (STATE LEAD PROJECT)
• PRIVATE PARTY PROJECT MANAGER (PRIVATE PARTY LEAD)
ATSDR
• HEALTH ASSESSMENTS
CORPS
• RD/RA ACTIVITIES (FEDERAL LEAD PROJECT)
SECONDARY USERS
(ENF/STATE/ATSDR/CORPS)
• GENERIC DATA NEEDS
ATSDR PAPER
STATE STANDARDS
CHAIN OF CUSTODY
• SITE SPECIFIC DATA NEEDS
SPECIAL PATHWAY INFO
PRP IDENTIFICATION
RD/RA NEEDS
TECHNICAL SUPPORT
(ESD/OTHERS/TAC TEAM)
• UPON REQUEST BY RPM
SAMPLING/ANALYTICAL SUPPORT
REGULATORY REQUIREMENTS
PROJ REVIEW/AUDIT
(ESD/ORC/HQ)
• QA INTEGRITY
• COMPLIANCE WITH POLICY
INPUT
OUTPUT

FIGURE 3-2
DECISION MAKER DATA USERS INTERACTION

The preliminary data are confirmed by on-site observations. The goals of the initial site inspection are as follows:

- Utilizing field analytical procedures, obtain data on volatile chemical contaminants, radioactivity, and explosivity hazards to determine appropriate health and safety levels.
- Estimate if any conditions could pose an imminent danger to public health
- Confirm the information contained in previous documents.
- Record observable data missing in previous documents.
- Update site conditions if undocumented changes have occurred.
- Perform an inventory of possible off-site sources of contamination.
- Obtain data such as location of access routes, sampling points and the site organization requirements for the field investigation.

Geophysical surveys, limited field screening, or limited field analysis may be performed during the initial site inspection. This type of initial sampling may help determine the variability of the media, provide background information, or determine if site conditions have changed.

### 3.2.2 REVIEW AVAILABLE DATA

For many sites, previous studies have provided useful information upon which further investigations can be based. The quality of the data should be analyzed to determine its usability. These evaluations determine the uncertainty associated with the conclusions drawn from the data.

A number of factors relate to the quality of data and its adequacy for use in the RI/FS process, including the following considerations:

- Age of the data
- Analytic methods used
- Detection limits of methods
- QA/QC procedures and documentation

Methods used for sample collection are as important to consider as the methods used for sample analysis. These considerations fall into two broad categories: statistical and standard operating procedures (SOPs). The statistical considerations relate to the representativeness of the data and the level of confidence that may be placed in conclusions drawn from the data (confidence levels are discussed in Appendix A). Following SOPs ensures sample integrity and data comparability and reduces sampling and analytical error. Typical issues to consider include the following:

- Sampling objective and approach
- Sample collection methods
- Chain of custody documentation
- Sample preservation techniques

- Sample shipment methods
- Holding times

If limited or no information exists on sample collection, preservation techniques or holding times, the data should be interpreted with caution.

### 3.2.3 ASSESS ADEQUACY OF DATA

The uncertainty associated with each data measurement activity should be considered when data are evaluated. Although data may be validated analytically, the level of precision of a particular data point may not provide sufficient certainty for use in a decision. (Precision and its use in decision making is discussed in Appendix A.)

It is important to recognize the distinction between uncertainty associated with a measurement activity and uncertainty associated with a decision during development of DQOs. The uncertainty associated with a measurement activity is a function of the statistical distribution of errors for each reported concentration value. At a typical site, many measurement activities are performed and many data are obtained. Decisions are made after analyzing and summarizing the data. The uncertainty associated with a decision is a function of the statistical distributions of the factors (statistics) which were used in reaching the decision. Assessment of data adequacy, then, has two steps. The first step is data validation. The second step is determining if the data is sufficient to reduce the uncertainty surrounding a decision to an acceptable level.

Data validation identifies invalid data and qualifies the usability of the remaining data. The output of data validation is qualitative or quantitative statements of data quality. Once the quality of individual measurements are known, a compilation of all data points into a cohesive statement regarding, for example, the areal extent of contamination can be made. Areas requiring remediation can then be delineated based on specific action levels. The confidence associated with such a remediation decision incorporates both the confidence in individual measurements as well as in the estimated area requiring remediation. These types of confidence statements can only be made if a detailed statistical evaluation of the data is undertaken. Details regarding establishment of criteria and action levels are discussed in Section 4.0 of this document.

## 3.3 DEVELOP CONCEPTUAL MODEL

Conceptual models describe a site and its environs and present hypotheses regarding the contaminants present, their routes of migration, and their potential impact on sensitive receptors. The hypotheses are tested, refined and modified throughout the RI/FS. Figure 3-3 depicts the basic elements of a conceptual model for an uncontrolled hazardous waste site. The development of a conceptual model for a hypothetical site is presented in Section 3.4 of the Example Scenario document.

### 3.3.1 EVALUATION OF THE CONCEPTUAL MODEL

The conceptual model should be detailed enough to address potential or suspected sources, types and concentrations of contaminants, affected media, rates and routes of migration, and receptors. Figure 3-4 presents an illustration which supports a conceptual model.

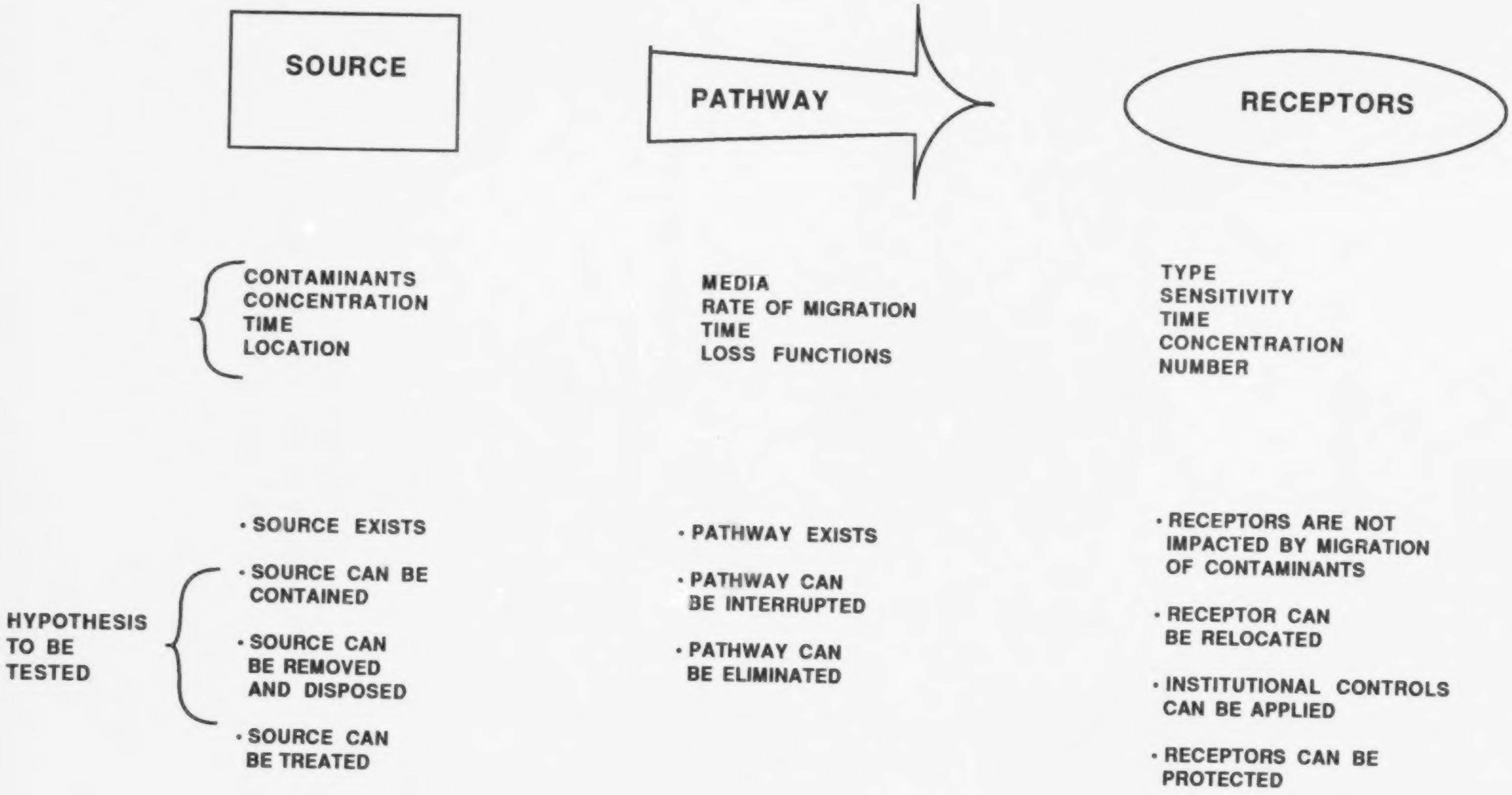
SOURCE
PATHWAY
RECEPTORS
CONTAMINANTS
CONCENTRATION
TIME
LOCATION
MEDIA
RATE OF MIGRATION
TIME
LOSS FUNCTIONS
TYPE
SENSITIVITY
TIME
CONCENTRATION
NUMBER
HYPOTHESIS TO BE TESTED
• SOURCE EXISTS
• SOURCE CAN BE CONTAINED
• SOURCE CAN BE REMOVED AND DISPOSED
• SOURCE CAN BE TREATED
• PATHWAY EXISTS
• PATHWAY CAN BE INTERRUPTED
• PATHWAY CAN BE ELIMINATED
• RECEPTORS ARE NOT IMPACTED BY MIGRATION OF CONTAMINANTS
• RECEPTOR CAN BE RELOCATED
• INSTITUTIONAL CONTROLS CAN BE APPLIED
• RECEPTORS CAN BE PROTECTED

FIGURE 3-3
ELEMENTS OF A CONCEPTUAL EVALUATION MODEL

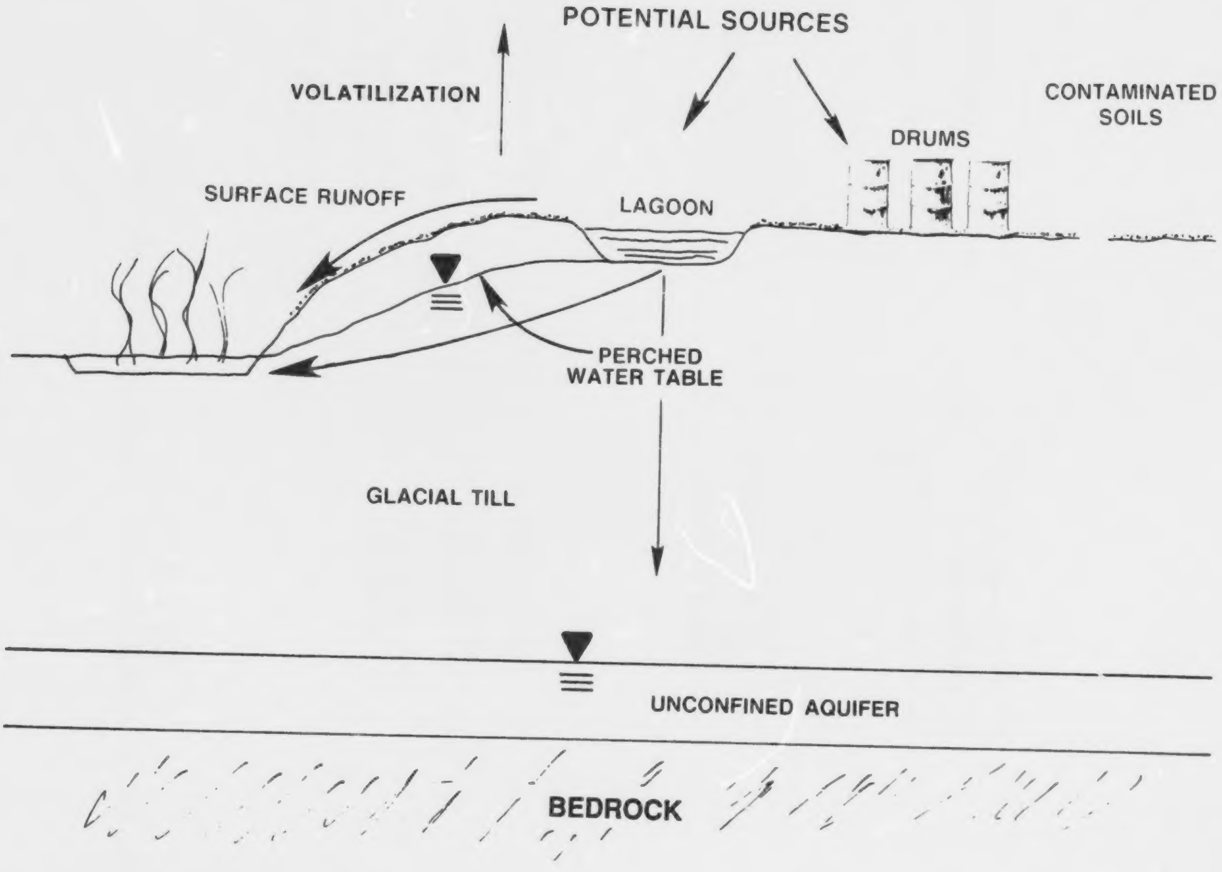
POTENTIAL SOURCES
VOLATILIZATION
CONTAMINATED SOILS
DRUMS
SURFACE RUNOFF
LAGOON
PERCHED WATER TABLE
GLACIAL TILL
UNCONFINED AQUIFER
BEDROCK

FIGURE 3-4
EXAMPLE CONCEPTUAL MODEL ILLUSTRATION

The following are assessed during development of the conceptual model to determine appropriate remedial and/or removal actions at a site:

- Population, environmental, and welfare concerns at risk
- Routes of exposure
- Spatial distribution of contaminants
- Atmospheric dispersion potential and proximity of targets
- Amount, concentration, hazardous properties, environmental fate and form of the substance(s) present
- Hydrogeological factors
- Climate
- Extent to which the source can be adequately identified and characterized
- Potential for reuse, recycling or treatment of substances at the site
- Likelihood of future releases if the substances remain on-site
- Extent to which natural or man-made barriers currently contain the substances and the adequacy of the barriers
- Assessment of the potential pathways of migration and a model of such
- Extent to which the substances have migrated or are expected to migrate from their source and whether migration poses a threat to public health, welfare, or the environment
- Extent to which contamination levels exceed applicable or relevant and appropriate federal or state requirements (ARARs) relating to public health or environmental standards and criteria

Data evaluation should be undertaken at the initiation of any remedial action program and at each point within the program that additional data are obtained. Additional data collected during the RI are used to expand the conceptual model and determine if sufficient data of adequate quality have been obtained to address the issues of concern.

### 3.3.2 COMPUTER MODELS

Common, but difficult, questions to be addressed during a remedial action program deal with defining the extent of contamination, setting action limits and establishing the acceptable likelihood of an incorrect decision. These types of questions generally require that data be evaluated utilizing tools such as ground water models, air quality models, and/or geostatistical methods. Ground water models include several levels of analysis: simple graphical techniques, analytical solution techniques, and numerical solution techniques. Using this broad definition of modeling, one of these techniques is almost always applied to examine a ground water contamination problem. Thus, the primary question becomes not when to use modeling, but what level of analysis is required to meet the objectives of the study.

The role of modeling must be evaluated with respect to the entire site investigation. The evaluation of small sites with relatively uniform geology may be accomplished by the use of simple analytical models.

Larger sites with complex stratigraphy, involving contamination in multiple layers and with variable aquifer parameters, can only be represented by a sophisticated numerical model.

A common misconception about ground water modeling and geostatistical techniques is that they are applied only during the final stages of an RI, after all the data are collected. Modeling techniques can be applied throughout the RI. For example, during the early stages of an RI, modeling can be used to guide the data collection program. Sensitivity analyses can help identify the types of data needed, as well as critical sampling locations. As data collection proceeds during a phased RI, or when a large amount of data exist from previous investigations, models can be used to provide a consistent framework for organizing the data. During the latter stages of an FS, models can be applied to predict the future behavior of a ground water system under natural or artificial stresses, such as varied pumping schemes.

## 3.4 SPECIFY OBJECTIVES/DECISIONS

In a broad sense, the objective of a remedial action program is to determine the nature and extent of the release or threat of release of hazardous substances and to select a cost effective remedial action to minimize or eliminate that threat. Achieving this broad objective requires that several complicated and interrelated activities be performed, each having objectives, acceptable levels of uncertainty, and attendant data quality requirements. The expression of these objectives in clear precise decision statements is the first step toward the development of a cost-effective data collection program.

### 3.4.1 OBJECTIVES

Project objectives should address major areas of the remedial process. These include characterizing the site with respect to the environmental setting, proximity and size of human population, and nature of the problem; identifying potential remedies; and determining specific performance levels of the potential remedies.

Specifying the objectives can be thought of as identifying problems to be solved. Objectives tend to be geared toward separate media or sources. However, these objectives should be consistent with the ultimate objective of selecting a remedial alternative(s) to address the entire site. Table 3-1 lists general RI/FS objectives.

Defining the types of decisions which will be made regarding remedial actions requires a clear understanding of the problems posed by the site and awareness of the consequences of making a wrong decision.

### 3.4.2 DECISION TYPES

The consequences of making a wrong decision regarding site remediation will vary depending on the situation. For example, a decision may be made not to implement a remedial alternative designed to mitigate the migration of contaminants in ground water because the data indicate that dispersion and degradation of the contaminants will reduce concentrations to health-based levels. If the contaminants actually migrated beyond the site and were encountered in the ground water system, it may be suggested that a wrong decision was made. The consequences of this wrong decision at a site where residents derive their drinking water from the contaminated aquifer would be different from the consequences of contamination of an aquifer which was not used as a water supply.

The consequences of a wrong decision must be weighed for each major decision to be made during the remedial action process. Where the consequences of a wrong decision carry significant public health, safety or environmental impacts, greater attention must be paid to obtaining the data required to ensure that the decision is sound.

## TABLE 3-1

## General RI/FS Objectives

| Objective | RI Activity | FS Activity |
|---|---|---|
| - Determine presence or absence of contaminants | - Establish presence/absence of contaminants at source and in all pathways. | - Evaluate applicability of no action alternative for source areas/pathways. |
| - Determine types of contaminants | - Establish "nature" of contaminants at source and in pathways; relate contaminants to PRP-cost recovery | - Evaluate environmental/public health threat; identify applicable remedial technologies. |
| - Determine quantities (concentrations) of contaminants | - Establish concentration gradients | - Evaluate costs to achieve applicable or relevant and appropriate standards |
| - Determine mechanism of contaminant release to pathways | - Establish mechanics of source/ pathway(s) interface | - Evaluate effectiveness of containment technologies |
| - Determine direction of pathway(s) transport | - Establish pathway(s)/transport route(s), Identify potential receptor(s) | - Identify most effective points in pathway to control transport of contaminants |
| - Determine boundaries of source(s) and pathways | - Establish horizontal/vertical boundaries of source(s) and pathway(s) of contamination | - Evaluate costs to achieve relevant/applicable standards; identify applicable remedial technologies |
| - Determine environmental/public health factors | - Establish routes of exposure, and environmental and public health threat | - Evaluate applicable standards or risk; identify applicable remedial technologies |
| - Determine source/pathway contaminant characteristics with respect to mitigation (bench studies) | - Establish range of contaminants/ concentrations | - Evaluate treatment schemes |

The risk of making a wrong decision is related to the quantity and quality of information available. As shown in Figure 3-5, as the quantity and quality of data increase, the risk of making a wrong decision generally decreases. This is not a linearly inverse relationship since at some point the collection of additional data or improvement of data quality will not significantly decrease the risk of making wrong decisions.

Data quantity and data quality are independent variables which must be considered jointly during assessment of the consequences of making a wrong decision. Collecting increasing quantities of data points which are of low quality may not add significantly to the reduction of risk of making a wrong decision. Increasing the data quality of a limited number of samples may not add significantly to the body of knowledge to be used in making a decision.

The value of obtaining additional data or increasing data quality has traditionally been based on professional judgment for RI/FS projects. The intent of the DQO process is to provide a systematic approach for the evaluation of the risk associated with making a wrong decision and for determining levels of uncertainty associated with decisions to provide a framework for the RPM.

## 3.5 REFERENCES

Federal Register. 1985. National Oil and Hazardous Substances Pollution Contingency Plan. Final Rule. Vol. 50, No. 224. November 20.

U.S. Environmental Protection Agency (EPA). 1985a. Guidance on Remedial Investigations Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/002. June.

___. 1985b. Guidance on Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response, Office of Waste Programs Enforcement, Office of Solid Waste and Emergency Response, Washington, D.C. Office of Research and Development, Cincinnati, Ohio. EPA/540/G-85/003. June.

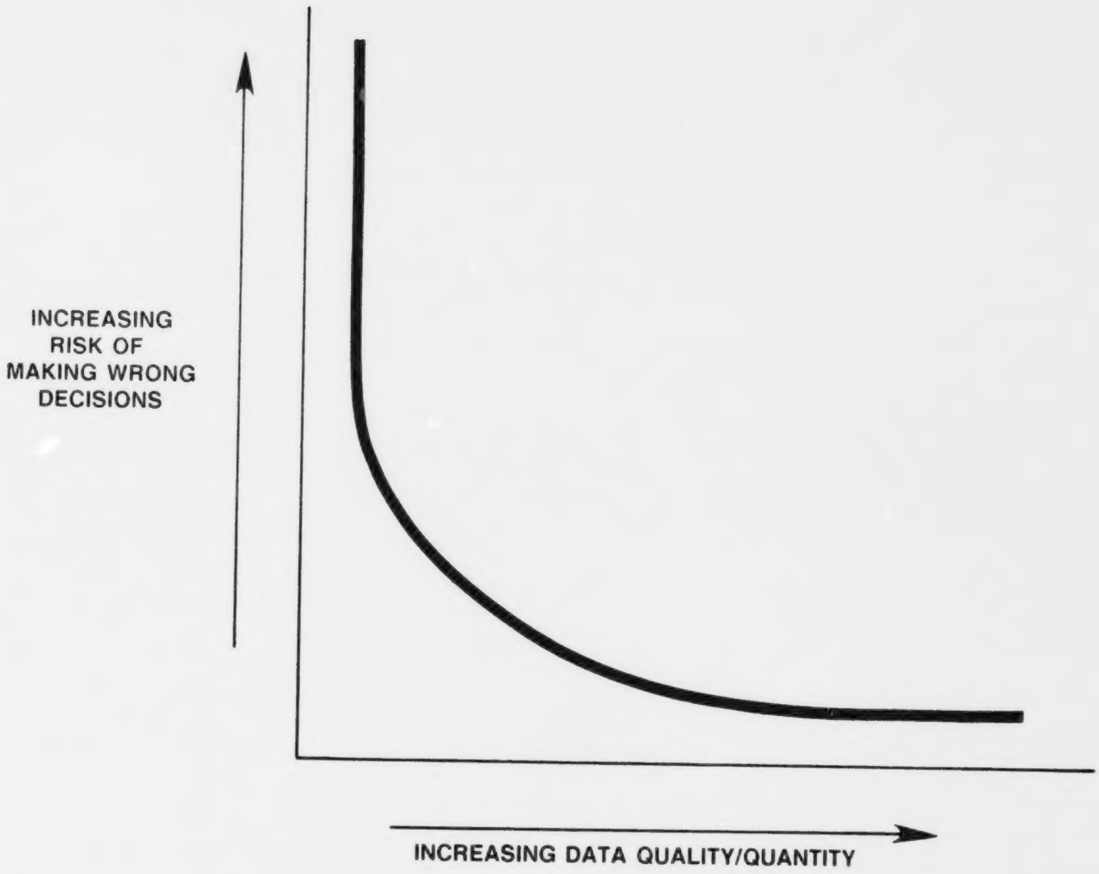

**FIGURE 3-5
RELATIONSHIP OF RISK AND DATA
QUALITY/QUANTITY**

## 4.0 RI/FS DQO STAGE 2 - IDENTIFY DATA USES/NEEDS

Stage 2 of the DQO process defines data uses and specifies the types of data needed to meet the project objectives. Although data needs are identified generally during Stage 1, it is during Stage 2 that specific data uses are defined.

The major elements of Stage 2 of the DQO process, as identified in Figure 4-1, are:

- Identify data uses
- Identify data types
- Identify data quality needs
- Identify data quantity needs
- Evaluate sampling/analysis options
- Review PARCC parameters

Stage 2 begins after the conceptual model is developed and overall project objectives are established. The conceptual model and the general decisions become the basis for determining data uses and data needs. Stage 1 determines if existing data meet the project objectives. If the existing data are sufficient, there is no need to collect additional data. If the data are insufficient, the types, quality, and quantity of data which must be collected will be determined in Stage 2.

### 4.1 IDENTIFY DATA USES

Data uses must be stated very specifically to serve their purpose in development of DQOs. This task should not be taken lightly.

As a demonstration of the importance of accurately specifying data uses consider the following example. Ground water samples are to be obtained at a site with known shallow ground water contamination. The homes in the area derive water from private wells which tap a deeper bedrock aquifer. Based upon the DQO approach, professional experience, and program guidelines provided by the RPM, the contractor decides that ground water from the bedrock aquifer should be sampled. However, additional questions to address during Stage 2 of the DQO process include:

- How many samples are required?
- Where should samples be obtained?
- How many QA/QC samples are needed (field trip blanks, collocated samples, field and laboratory duplicates, spikes)
- Will data be used to determine if an alternative water supply should be provided to affected homes?
- At what contaminant level are water supplies believed to be affected?
- Will decisions be based upon analysis of samples from private water supply wells or from monitoring wells?

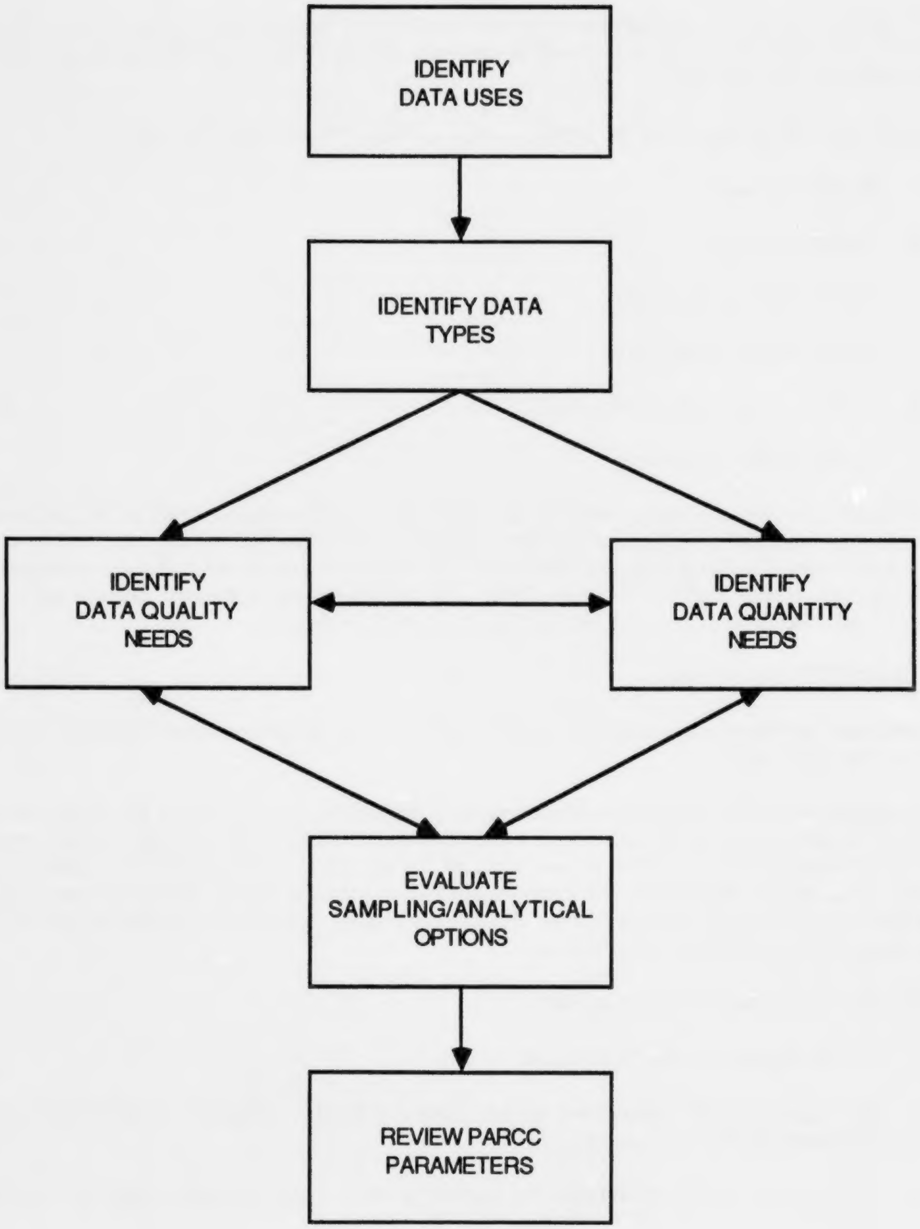
IDENTIFY DATA USES
IDENTIFY DATA TYPES
IDENTIFY DATA QUALITY NEEDS
IDENTIFY DATA QUANTITY NEEDS
EVALUATE SAMPLING/ANALYTICAL OPTIONS
REVIEW PARCC PARAMETERS

**FIGURE 4-1**
**DQO STAGE 2 ELEMENTS**

- If contaminants are not detected in private water supply wells but are detected in monitoring wells, how will data be used to assess risks to receptors?

As demonstrated, the list of questions which can be generated to evaluate a simplistic problem in one medium can be quite extensive.

### 4.1.1 DATA USE CATEGORIES

RI/FS data uses can be described in general purpose categories. These categories represent generic uses but vary on a site-by-site basis. Further, specific sites may require data for purposes other than those described here. The categories listed in Table 4-1 represent the most common RI/FS data uses. Tables 4-1 and 4-2 are forms that can be used by project managers to document the thought processes involved in DQOs and the S&A plan. The categories do not represent different data qualities, only different uses which may require data of a given quality. In other words, data collected for a site at a given level of quality may be used for different purposes. The data use categories are briefly described below:

- Site Characterization - Data are used to determine the nature and extent of contamination at a site. This category is usually the one that requires the most data collection. Site characterization data are generated through the sampling and analysis of waste sources and environmental media.

- Health and Safety - Data are typically used to establish the level of protection needed for investigators or workers at a site, and if there should be an immediate concern for the population living within the site vicinity.

- Risk Assessment - Data are used to evaluate the threat posed by a site to public health and the environment. Risk assessment data are generated through the sampling and analysis of environmental and biological media, particularly where the potential for human exposure is great.

- Evaluation of Alternatives - Data are used to evaluate various remedial technologies. Engineering data are collected in support of remedial alternative evaluation and to develop cost estimates. This may involve performing bench-scale or pilot scale studies to determine if a particular process or material may be effective in mitigating site contamination.

- Engineering Design of Alternatives - Data collected during the RI/FS can be used for engineering design purposes to develop a preliminary data base in reference to the performance of various remedial technologies. Data types collected during the RI/FS which are applicable to the RD process include waste characterization and preliminary volume estimates (these estimates usually need to be refined further by additional data collection activities during the RD/RA).

- Monitoring During Remedial Action - During the the remedial action, samples can be taken to assess the effectiveness of the action. Based on the analysis of these samples, corrective measures may be taken.

- PRP Determination - Data may be used to help establish liability at multiple-party sites. For known RPs, data are used to link their wastes to those found on the site and to pollutants released to the environment, and for unknown RPs, by comparing the site wastes to pollutant profiles of known waste streams. Data are also used for injunctive actions and cost recovery.

Once the data use categories are listed, the intended uses must be prioritized. Establishing an order of priority for the intended data uses will help identify the most demanding use of each type of data, i.e.,

# TABLE 4-1
# DATA USES

**SITE**
NAME________________
LOCATION________________
NUMBER________________
PHASE________________
RI1 RI2 RI3 ERA FS RD RA

EPA REGION
________

DATE________________
CONTRACTOR________________
SITE MANAGER________________

| DATA USE / MEDIA | SITE CHARACTERIZATION (INCLUDING HEALTH & SAFETY) | RISK ASSESSMENT | EVALUATION OF ALTERNATIVES | ENGINEERING DESIGN OF ALTERNATIVES | MONITORING DURING REMEDIAL ACTION | PRP DETERMINATION | OTHER ________ |
|---|---|---|---|---|---|---|---|
| SOURCE SAMPLING TYPE ________ | | | | | | | |
| SOIL SAMPLING | | | | | | | |
| GROUND WATER SAMPLING | | | | | | | |
| SURFACE WATER/SEDIMENT SAMPLING | | | | | | | |
| AIR SAMPLING | | | | | | | |
| BIOLOGICAL SAMPLING | | | | | | | |
| OTHER ________ | | | | | | | |

NOTE: CHECK APPROPRIATE BOX (ES)

CDM SF DQO 1.001

## TABLE 4-2
## DQO SUMMARY FORM

**1. SITE**

NAME ____________________
LOCATION ____________________
NUMBER ____________________

**EPA REGION** _____

**PHASE** ____________________
RI 1 RI 2 RI 3 ERA FS RD RA
*( CIRCLE ONE )*

| | | | | | | |
|---|---|---|---|---|---|---|
| **2. MEDIA** *(CIRCLE ONE)* | SOIL | GW | SW/SED | AIR | BIO | OTHER<br>______ |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **3. USE** *(CIRCLE ALL THAT APPLY)* | SITE CHARAC. (H&S) | RISK ASSESS. | EVAL. ALTS. | ENG'G DESIGN | PRP DETER. | MONITORING REMEDIAL ACTION | OTHER<br>______ |

**4. OBJECTIVE** ____________________
____________________
____________________
____________________

**5. SITE INFORMATION**

AREA ____________________ DEPTH TO GROUND WATER ____________________
GROUND WATER USE ____________________
SOIL TYPES ____________________
SENSITIVE RECEPTORS ____________________

**6. DATA TYPES** *(CIRCLE APPROPRIATE DATA TYPES)*

| A. ANALYTICAL DATA | | | B. PHYSICAL DATA | |
|---|---|---|---|---|
| pH | PESTICIDES | TOX | PERMEABILITY | HYDRAULIC HEAD |
| CONDUCTIVITY | PCB | TOC | POROSITY | PENETRATION TEST |
| VOA | METALS | BTX | GRAIN SIZE | HARDNESS |
| ABN | CYANIDE | COD | BULK DENSITY | ______ |
| TCLP | ______ | ______ | ______ | ______ |

**7. SAMPLING METHOD** *(CIRCLE METHOD(S) TO BE USED)*

| | | | | |
|---|---|---|---|---|
| ENVIRONMENTAL | BIASED | GRAB | NON- INTRUSIVE | PHASED |
| SOURCE | GRID | COMPOSITE | INTRUSIVE | ______ |

**8. ANALYTICAL LEVELS** *(INDICATE LEVEL(S) AND EQUIPMENT & METHODS)*

LEVEL 1 FIELD SCREENING - EQUIPMENT ____________________
LEVEL 2 FIELD ANALYSIS - EQUIPMENT ____________________
LEVEL 3 NON-CLP LABORATORY - METHODS ____________________
LEVEL 4 CLP/RAS - METHODS ____________________
LEVEL 5 NON STANDARD ____________________

**9. SAMPLING PROCEDURES**

BACKGROUND - 2 PER EVENT OR ____________________
CRITICAL (LIST) ____________________
PROCEDURES ____________________

**10. QUALITY CONTROL SAMPLES** *(CONFIRM OR SET STANDARD)*

A. FIELD
COLLOCATED - 5% OR __________
REPLICATE - 5% OR __________
FIELD BLANK - 5% OR __________
TRIP BLANK - 1 PER DAY OR __________

B. LABORATORY
REAGENT BLANK - 1 PER ANALYSIS BATCH OR __________
REPLICATE - 1 PER ANALYSIS BATCH OR __________
MATRIX SPIKE - 1 PER ANALYSIS BATCH OR __________
OTHER ____________________

**11. BUDGET REQUIREMENTS**

BUDGET ____________________ SCHEDULE ____________________
STAFF ____________________

**CONTRACTOR** ____________________ **PRIME CONTRACTOR** ____________________
**SITE MANAGER** ____________________ **DATE** ____________________

FOR DETAILS SEE SAMPLING & ANALYSIS PLAN

CDM SF DQO 1.002

## TABLE 4-2 (CONTINUED)

## DQO SUMMARY FORM INSTRUCTIONS

**1. SITE** - Identify the site and phase of the work to be conducted
- NAME - Site name or assignment as stated in the WA
- LOCATION - City or Town County and State where site is located
- NUMBER - Site number as stated in the WA
- EPA REGION - EPA Region where the site is located
- PHASE - Circle work phase for which DQO's are being developed: (number sequentially for each phase as appropriate):
  RI - Remedial
  ERA - Expedited Response Action
  FS - Feasibility Study
  RD - Remedial Design
  RA - Remedial Action

**2. MEDIA** - Circle the media being investigated; only one form will be completed for each media.
- SOIL - Surface and subsurface soils
- GW - Ground water
- SW/SED - Surface water and sediment (a sediment sample will be taken if possible at each surface water sampling location)
- AIR - Air quality and respirable dust monitoring
- BIO - Biological monitoring, flora and fauna
- OTHER - Indicate other "media" being investigated i.e. buildings, underground conduits, etc.

**3. USE** - Circle the intended use(s) of the data to be developed.
- SITE CHARAC. (H&S) - Site characterization which includes a determination of the level(s) of health and safety protection required at the site
- RISK ASSESS - Risk assessment, data to be used to perform the endangerment assessment or public health evaluation
- EVAL. ALTS. - Evaluate alternatives, data will be used to evaluate or screen remedial/technological alternatives
- ENG'G DESIGN - Data will be used to perform detailed engineering design of remedy
- MONITORING - Data will be used to monitor during remedy implementation or establish baseline conditions for long term monitoring after site remediation
- PRP DETERMINATION - Data will be used to confirm/fingerprint contaminants to specific potentially responsible parties for possible furture or pending enforcement actions
- OTHER - Indicate other specific data uses

**4. OBJECTIVE** - Provide a concise, specific statement that answers the question "Why am I taking these samples?"

**5. SITE INFORMATION** - Provide the site information necessary to gain an overview of the site and the relative complexity and extent of data requirements
- AREA - Indicate the area of the site in acres and an indication of the configuration (length and width)
- DEPTH TO GROUND WATER - Indicate the depth to ground water from the ground surface, to the extent known identify seasonal fluctuation and the depth and thickness of multiple aquifers
- GROUND WATER USE - Identify both potable and non-potable ground water use(s) by aquifer, if appropriate, and the point(s) of extraction relative to the site
- SOIL TYPES - Identify, to the extent known, the site soil strata and relative depths below ground surface
- SENSITIVE RECEPTORS - Identify population and environmental concerns, relative to the site, which could be impacted by contaminant migration

**6. DATA TYPES** - Circle the appropriate analytical and physical data required to to determine the type, degree, extent and migration characteristics of the contaminants and the required site characteristics. The selection of data types required must be developed by the site manager with the data users as described in section 3.2

**7. SAMPLING METHODS** - Circle the appropriate sampling method(s) to be used in obtaining the required data in accordance with the objectives above
- ENVIRONMENTAL - Refers to media sampling of air, water, soils and the biological environment to determine the extent of contamination
- SOURCE - Refers to the sampling of the actual contamination source(s)
- BIASED - Refers to sampling which focuses on a specific site area, characteristic or problem factor based upon site knowledge and/or modeling
- GRID - Refers to unbiased sampling which provides a representative estimate of contamination problem over the entire site
- GRAB - Refers to discrete samples which are representative of a specific location at a specific point in time.
- COMPOSITE - The mixture of a number of grab samples to represent the average properties of the parameters of concern over athe extent of the area sampled
- NON-INTRUSIVE - Refers to obtaining data using methods and equipment that do not require the physical extraction of sample from the media being sampled
- INSTRUSIVE - Refers to physically extracting samples from the media being sampled
- PHASED- Refers to performing discrete time-phased sampling events and using the information obtained in the previous event to refine the subsequent sampling event

**8. ANALYTICAL LEVELS** - The analytical levels are described in Section 9 of the Guidance
- LEVEL 1 FIELD SCREENING - EQUIPMENT - Identify the field monitoring equipment to be used and the manufacturer's specified detection limits when known
- LEVEL 2 FIELD ANALYSIS - EQUIPMENT - Identify the field analysis to be used and the historically achievable instrument detection limits
- LEVEL 3 NON-CLP LABORATORY - METHODS -Identify the laboratory method(s) to be used and the historically achieveable precision and accuracy when available
- LEVEL 4 CLP/RAS - METHODS - Identify the CLP laboratory method(s) to be used and the historically achievable precision and accuracy
- LEVEL 5 NON-STANDARD - Specify requirement for non-standard analysis, analytical procedures to be used and required precision and accuracy

**9. SAMPLING PROCEDURES** - The procedures to be used in obtaining the required samples are to be defined, a description of the critical samples is to be provided and the requirement of obtaining a minimum of two background samples per sampling event is to be confirmed or the deviation from this minimum standard defined

**10. QUALITY CONTROL SAMPLES** - The identified minimum standards for the field and laboratory quality control samples must be confirmed or revised on a site specific basis

**11. BUDGET REQUIREMENTS** - Based upon the analysis summarized above the critical resource requirements shall be defined
- BUDGET - The estimated cost of the sampling and analysis shall be presented in dollars
- SCHEDULE - The total time required to perform the sampling and the estimated time, as appropriate to perform the analysis shall be presented by calendar days, by phase
- STAFF - The key staff disciplines required to perform the sampling shall be identified

The form shall identify the contractor directly responsible for the work the prime contractor and must be signed and dated by the site manager.

the use requiring the highest level of confidence, and therefore the lowest level of uncertainty. The data quality required will be a function of the acceptable limits of uncertainty established by the decision maker. The limits on uncertainty will drive the selection of both the analytical and sampling approaches.

### 4.1.2 RI/FS USES

During the evaluation of data uses, the potential remedial options which will be considered during the RI/FS must be reviewed.

As mandated by the Superfund Amendments and Reauthorization Act of 1986 (SARA), treatment alternative should be developed ranging from an alternative which minimizes long term management of residuals to an alternative involving treatment that significantly reduces toxicity, mobility, or volume as a principal element. In addition, a containment option involving little or no treatment and a no action alternative should also be developed.

For each of the appropriate action categories, the following information or analyses should be considered during the DQO process:

- List of candidate remedial actions
- Method by which the initial alternatives will be screened, including effectiveness criteria, implementability criteria, and cost criteria
- Detailed effectiveness screening will examine whether the alternatives protect public health and the environment; meet ARARs; cause a reduction in toxicity, mobility, or volume; and provide acceptable reliability.
- Detailed implementability screening will examine the technical feasibility, availability, and administrative feasibility of each alternative.
- Detailed cost screening will examine the capital, O&M, and replacement cost as well as the present worth of the alternatives.
- Both the short and long-term effects of the screening factors must be assessed and the alternatives must be compared to identify their relative strengths and weaknesses.

The remedial process involves a number of data collection activities, each having specific objectives. Since the objectives require varying degrees of data quality, it is critical to identify the specific use to which each set of data will be applied.

## 4.2 IDENTIFY DATA TYPES

Data use categories define the general purposes for which data will be collected during the RI. Based on the intended uses, a concise statement regarding the data types needed can be developed. After identifying the data types and uses, data quality needs can be defined, and a systematic evaluation of sampling and analysis options can be performed.

Data types can be specified in broad groups initially, such as background samples or media samples, and then these broad groups are divided into more specific components. Figure 4-2 illustrates the process of continual refinement of data types for a hypothetical ground water contamination problem. The process should be followed for each media of interest or each source material. The result of completing the entire decision matrix is the specification of the data type needed for each intended data use.

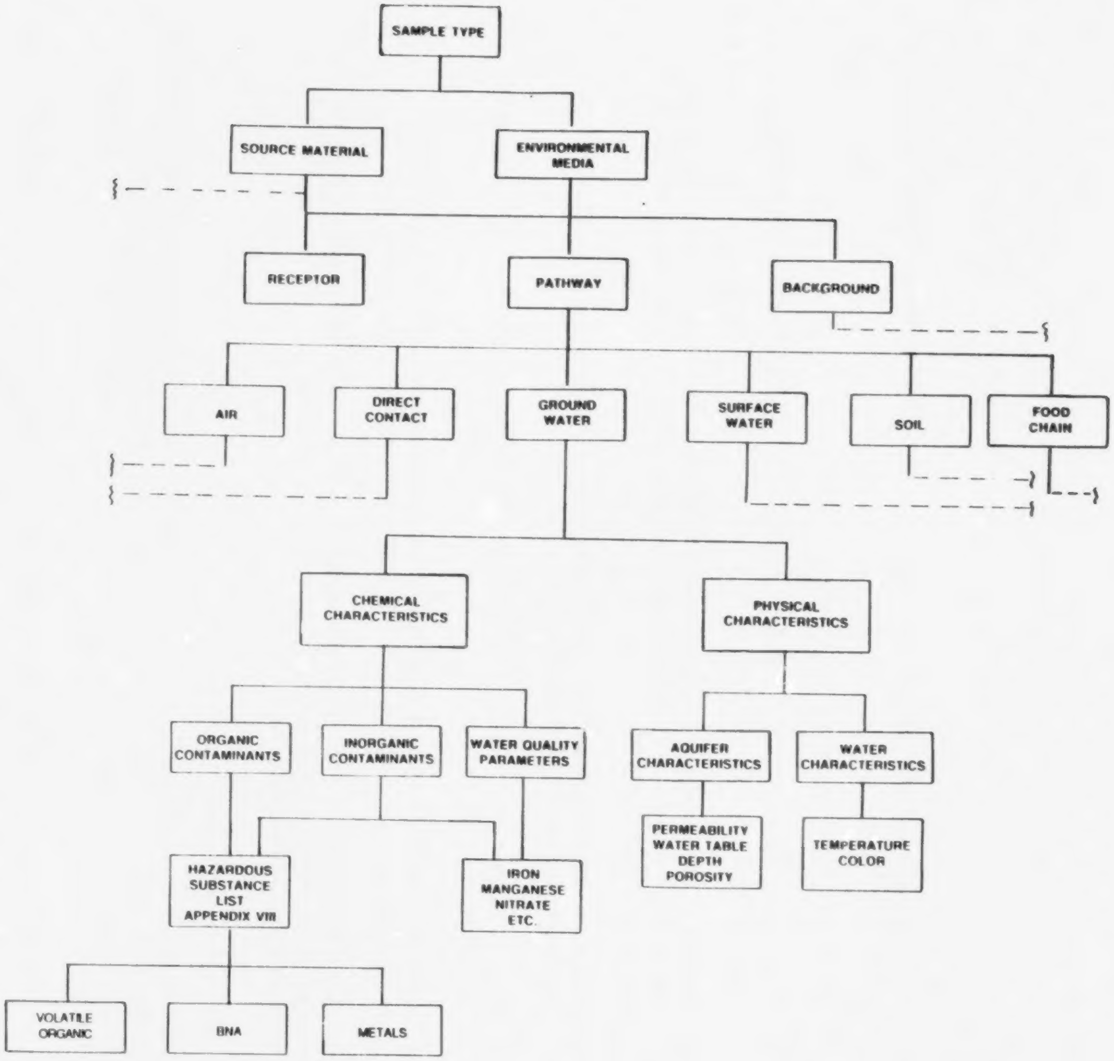
SAMPLE TYPE
SOURCE MATERIAL
ENVIRONMENTAL MEDIA
RECEPTOR
PATHWAY
BACKGROUND
AIR
DIRECT CONTACT
GROUND WATER
SURFACE WATER
SOIL
FOOD CHAIN
CHEMICAL CHARACTERISTICS
PHYSICAL CHARACTERISTICS
ORGANIC CONTAMINANTS
INORGANIC CONTAMINANTS
WATER QUALITY PARAMETERS
AQUIFER CHARACTERISTICS
WATER CHARACTERISTICS
PERMEABILITY WATER TABLE DEPTH POROSITY
TEMPERATURE COLOR
HAZARDOUS SUBSTANCE LIST APPENDIX VIII
IRON MANGANESE NITRATE ETC.
VOLATILE ORGANIC
BNA
METALS

FIGURE 4-2
SAMPLE TYPE SPECIFICATION LOGIC DIAGRAM

Since environmental media and source materials are interrelated at uncontrolled hazardous waste sites, data types used to evaluate ground water contamination may also be used to evaluate soil contamination. By identifying data types by media, overlapping data needs are identified. The types of analyses performed on each sample must be determined while identifying data types. The analytical requirements are dictated by the use of the data.

The data types specified in Stage 2 should not be limited to chemical analytical parameters, but should also include physical parameters such as permeability and porosity, which are needed to evaluate contaminant migration. The level of detail in data type definition must be sufficient to allow for evaluation of sampling/analysis options during subsequent stages of the DQO process.

## 4.3 IDENTIFY DATA QUALITY NEEDS

### 4.3.1 DATA QUALITY FACTORS

Consideration of data quality needs should begin with the identification of data uses and data types. Important factors in defining data quality include:

- Prioritized data uses
- Appropriate analytical levels
- Contaminants of concern
- Level of concern
- Required detection limit
- Critical samples

These factors should be considered to define data quality needs in a general way at the start of an RI/FS. As work proceeds and more data become available, more precise statements can be made.

### Appropriate Analytical Levels

There is little or no information on many factors which critically affect data quality such as: sample variability, sample container cleanliness, effect of different sample collection and analytical preparation techniques, etc. Most available measurement data quality information addresses only the analytical technique. To provide some guidance, this section defines analytical levels and then indicates the levels appropriate to different generic RI/FS data uses. Appendix B of this document provides a more detailed discussion of analytical considerations.

The analytical levels are defined as follows:

- Level I - field screening or analysis using portable instruments. Results are often not compound specific and not quantitative but results are available in real-time. It is the least costly of the analytical options.

- Level II - field analyses using more sophisticated portable analytical instruments; in some cases, the instruments may be set up in a mobile laboratory on site. There is a wide range in the quality of data that can be generated. It depends on the use of suitable calibration standards, reference materials, and sample preparation equipment: and the training of the operator. Results are available in real-time or several hours.

- Level III - all analyses performed in an off-site analytical laboratory. Level III analyses may or may not use CLP procedures, but do not usually utilize the validation or documentation procedures required of CLP Level IV analysis. The laboratory may or may not be a CLP laboratory.

- Level IV - CLP routine analytical services (RAS). All analyses are performed in an off-site CLP analytical laboratory following CLP protocols. Level IV is characterized by rigorous QA/QC protocols and documentation.

- Level V - analysis by non-standard methods. All analyses are performed in an off-site analytical laboratory which may or may not be a CLP laboratory. Method development or method modification may be required for specific constituents or detection limits. CLP special analytical services (SAS) are Level V.

Levels III, IV and V all incorporate some time lag between submission of samples to the laboratory and receipt of results. Table 4-3 provides more information on these analytical levels; Table 4-4 identifies appropriate analytical levels for generic RI/FS data uses.

It can be seen from Table 4-4 that, for each generic data use, several analytical levels may be appropriate. The decision maker needs further criteria to select the most appropriate. Important criteria are the contaminants of concern and the level of concern for each contaminant.

Engineering design (see Table 4-4) usually requires considerations beyond analytical levels for chemical analyses. Physical property data (viscosity, soil organic carbon, etc.) are often necessary for engineering design. While most of the chemical analysis requirements for engineering design data needs can be accomplished by Level II, III and IV analyses, the physical property type analyses will usually fall within the Level V and "other" categories.

### Contaminants of Concern

At some sites it may be clear which contaminants are of concern because they have known adverse impacts on human health. In such cases, the appropriate health standards can be used to set levels of concern. Often a large number of contaminants are found at a site. In such cases it is not feasible or desirable to specify levels of concern for each observed contaminant. Rather, a small number of indicator chemicals are selected and levels of concern are determined for these chemicals. Indicator chemicals are the most toxic, mobile, persistent, or frequently occurring contaminants found on site. The process of selecting indicator contaminants is described in the Superfund Public Health Evaluation Manual (EPA 1985).

### Levels of Concern and ARARs

The level of concern specifies a concentration range above which some action may need to be taken. The level of concern is intimately linked with the action level, which defines the "level of cleanup" for remedial activities under SARA. In general, levels of concern are site specific issues and relate to site characterization and assessment. The applicable or relevant and appropriate requirements (ARARs), as mandated by SARA, are related to defining remedial design criteria and legal requirements.

An exact action level is not required before initiating an RI field investigation; however, a rough estimate is necessary to ensure that the chosen analytical methods are accurate at the level of concern. Also, knowledge of the level of concern can influence the number of samples required and the selection of analytical methods. For these reasons, an acceptable range of values should be specified. As work on a site progress and more data become available, the level of concern will be further refined and incorporated into the ROD as an action level.

# TABLE 4-3
# SUMMARY OF ANALYTICAL LEVELS APPROPRIATE TO DATA USES

| DATA USES | ANALYTICAL LEVEL | TYPE OF ANALYSIS | LIMITATIONS | DATA QUALITY |
|---|---|---|---|---|
| SITE CHARACTERIZATION<br>MONITORING DURING IMPLEMENTATION | LEVEL I | - TOTAL ORGANIC/INORGANIC VAPOR DETECTION USING PORTABLE INSTRUMENTS<br>- FIELD TEST KITS | - INSTRUMENTS RESPOND TO NATURALLY-OCCURING COMPOUNDS | - IF INSTRUMENTS CALIBRATED AND DATA INTERPRETED CORRECTLY, CAN PROVIDE INDICATION OF CONTAMINATION |
| SITE CHARATERIZATION<br>EVALUATION OF ALTERNATIVES<br>ENGINEERING DESIGN<br>MONITORING DURING IMPLEMENTATION | LEVEL II | - VARIETY OF ORGANICS BY GC; INORGANICS BY AA; XRF<br>- TENTATIVE ID; ANALYTE-SPECIFIC<br>- DETECTION LIMITS VARY FROM LOW ppm TO LOW ppb | - TENTATIVE ID<br>- TECHNIQUES/INSTRUMENTS LIMITED MOSTLY TO VOLATILES, METALS | - DEPENDENT ON QA/QC STEPS EMPLOYED<br>- DATA TYPICALLY REPORTED IN CONCENTRATION RANGES |
| RISK ASSESSMENT<br>PRP DETERMINATION<br>SITE CHARACTERIZATION<br>EVALUATION OF ALTERNATIVES<br>ENGINEERING DESIGN<br>MONITORING DURING IMPLEMENTATION | LEVEL III | - ORGANICS/INORGANICS USING EPA PROCEDURES OTHER THAN CLP CAN BE ANALYTE-SPECIFIC<br>- RCRA CHARACTERISTIC TESTS | - TENTATIVE ID IN SOME CASES<br>- CAN PROVIDE DATA OF SAME QUALITY AS LEVELS IV, NS | - SIMILAR DETECTION LIMITS TO CLP<br>- LESS RIGOROUS QA/QC |
| RISK ASSESSMENT<br>PRP DETERMINATION<br>EVALUATION OF ALTERNATIVES<br>ENGINEERING DESIGN | LEVEL IV | - HSL ORGANICS/INORGANICS BY GC/MS; AA; ICP<br>- LOW ppb DETECTION LIMIT | - TENTATIVE IDENTIFICATON OF NON-HSL PARAMETERS<br>- SOME TIME MAY BE REQUIRED FOR VALIDATION OF PACKAGES | - GOAL IS DATA OF KNOWN QUALITY<br>- RIGOROUS QA/QC |
| RISK ASSESSMENT<br>PRP DETERMINATION | LEVEL V | - NON-CONVENTIAL PARAMETERS<br>- METHOD-SPECIFIC DETECTION LIMITS<br>- MODIFICATION OF EXISTING METHODS<br>- APPENDIX 8 PARAMETERS | - MAY REQUIRE METHOD DEVELOPMENT/MODIFICATION<br>- MECHANISM TO OBTAIN SERVICES REQUIRES SPECIAL LEAD TIME | - METHOD-SPECIFIC |

## TABLE 4-4
## APPROPRIATE ANALYTICAL LEVELS - BY DATA USE

| DATA USE / ANALYTICAL LEVEL | SITE CHARACTERIZATION (INCLUDING HEALTH & SAFETY) | RISK ASSESSMENT | EVALUATION OF ALTERNATIVES | ENGINEERING DESIGN OF REMEDIAL ACTION | MONITORING DURING IMPLEMENTATION OF REMEDIAL ACTION | PRP DETERMINATION | OTHER ________ |
|---|---|---|---|---|---|---|---|
| LEVEL I | ✓ | | | | ✓ | | |
| LEVEL II | ✓ | | ✓ | | ✓ | | |
| LEVEL III | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| LEVEL IV | | ✓ | ✓ | ✓ | | ✓ | |
| LEVEL V | | ✓ | | ✓ | | ✓ | |
| OTHER | | | | ✓ | | | |

NOTE: CHECK APPROPRIATE BOX (ES)

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Determination of levels of concern is a site specific activity. The decision maker and data users (toxicologists, geologists, and engineers) must meet to determine the appropriate action level range for the site. Tables in Appendix E summarize potentially applicable or relevant and appropriate requirements and toxicity values. The standards do not consider simultaneous exposure from multiple routes. Standards may also be based on levels, durations, or frequencies of exposure that differ from those at a specific site. The standards and criteria that are used, especially when conducting public health assessments, must correspond to the media for which they are developed.

In the listing of applicable standards which can be used for selecting action levels, few standards are available for soil contamination. Generally, some type of modeling may be required to specify the level of concern for soil. The type of model selected will be based on the potential route of exposure. If contaminated soil is carried in the air and inhaled by receptors, air modeling may be required. If contaminants leach from soils into ground water and are transported to receptor wells, a ground water model may be required. These models are useful in assessing the potential impact resulting from migration of contaminants at a specified level of concern to a receptor at a specified cancer risk level, for instance. The available models are specified in the Superfund Exposure Assessment Manual (EPA 1985).

### Detection Limit Requirements

The level of concern selected directly affects data quality requirements. The sampling and analysis methods used must be accurate at the level of concern. Since sampling accuracy is hard to evaluate or control, it is extremely important that the analytical technique chosen has a detection limit well below the level of concern. This factor must be considered in evaluating analytical options. Appendix B provides more detailed information on detection limits. Appendix H lists CLP contractually required detection limits.

### Critical Samples

Critical samples are those for which valid data must be obtained to satisfy the objectives of the sampling and analysis task. An example of a critical data point may be an upgradient well in a ground water contamination study or any other data point considered vital to the decision making process. In some cases, taking critical samples in duplicate is appropriate.

### 4.3.2 COST ANALYSIS OF ALTERNATIVES

The program goal for developing cost estimates in feasibility studies is to estimate to within +50 percent and -30 percent of the actual cost of the selected remedial alternative. This puts requirements on the type and amount of data which must be collected during the field investigation and requires the decision maker to consider the range of potential remedial alternatives before planning the field investigation.

Where a possible alternative is source removal or treatment, the cost criteria may be used to determine the number of data required. If the cost of the remedial alternative is strictly proportional to the volume of material removed or treated, sufficient data must be obtained to determine the volume of material to within +50 percent and -30 percent. Normally, however, there is some uncertainty in the capital costs and the efficiency of the treatment or removal procedure. Therefore, it is necessary to determine the volume of contaminated soil as accurately as possible.

## 4.4 IDENTIFY DATA QUANTITY NEEDS

The number of samples which should be collected can be determined using a variety of approaches. The validity of the approach utilized is dependent on the characteristics of the media under investigation and the assumptions used to select sample locations. In situations where data are unavailable or limited, a phased sampling approach may be appropriate. Phase I data can be evaluated to determine the appropriate number of samples to be obtained in subsequent phases of the RI.

In the absence of available data, the data users and decision makers will be required to develop a rationale for selecting sampling locations. Questions to guide the data users in selecting appropriate locations could include:

- Do source materials still exist on the soil surface?
- Is there evidence of soil disturbance or vegetative stress based upon review of aerial photographs?
- Do geologic features in the area control ground water and surface water flow patterns?
- Do site conditions favor surficial soil erosion or wind erosion?
- Are sensitive receptors located in the vicinity of the site?

These types of questions can be addressed in the absence of any analytical data and will assist in identifying additional data needs. Subsequent discussions may lead to the recommendation that geophysical surveys or soil gas and other field screening studies be conducted in areas of soil disturbance. Collection of a limited number of samples from identified source materials or pathways, such as streams, may also be considered. Limited air sampling may also be warranted during the early stages of the RI to determine if organic vapors or particulates could pose a problem.

In situations where data are available, or as new data are added to the site's data base, statistical techniques may be utilized in determining the number of data required. Appendix A provides examples of the applicability and methodology of various statistical techniques.

Following evaluation of the data, the adequacy of the data to support a decision can be determined. If a higher degree of certainty in the decision is required (e.g., a more definitive statement regarding the extent of contamination), then additional data should be obtained in subsequent sampling phases. In all cases, the actual level of confidence in a decision can only be established following collection and evaluation of data. Therefore, at the completion of each data collection activity, data evaluation is critical.

## 4.5 EVALUATE SAMPLING/ANALYSIS OPTIONS

Following the identification of data uses, data types, and data quality needs, an evaluation of sampling and analysis options can be undertaken. Numerous sampling and analysis options could be developed for any data collection activity. The possible options are a function of the data types needed.

### 4.5.1 SAMPLING AND ANALYSIS APPROACH (PHASING)

Data collection activities must be designed to ensure maximum use of the data. Developing a sampling and analysis approach which ensures that appropriate levels of data quantity and quality are obtained may be accomplished by use of a phased RI approach and by the use of field screening techniques to direct the data collection activities. By subdividing the data collection program into a number of phases, the data can be obtained in a sequence which allows it to be used to direct subsequent data collection activities.

The time required for receipt of analytical data from laboratories often results in delays in an RI program. By utilizing field techniques for assessing contaminant concentrations or media characteristics, the RI can proceed with fewer delays.

Direct reading instruments which should be considered for use during the evaluation of a sampling/analysis approach include:

- Photoionization detectors (PIDs)
- Flame ionization detectors (FIDs)
- Hydrogen sulfide analyzers
- Hg vapor analyzers
- Respirable particulate meters
- Radiation meters
- Oxygen/explosimeters
- pH and conductivity meters

Other devices and field tests which allow for assessment of site conditions without the need for laboratory support include:

- Oil/water interface units
- Slug tests
- Infiltrometers

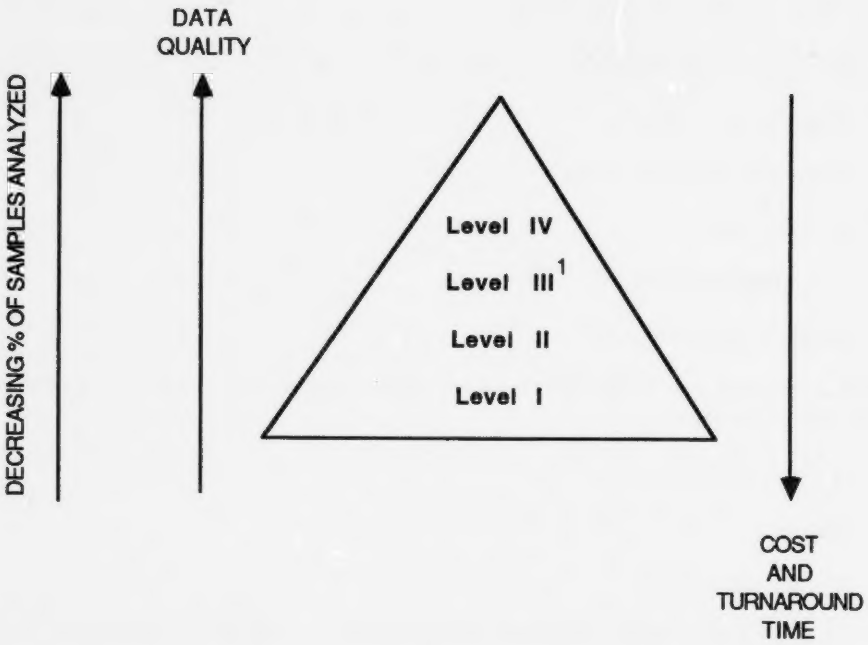
These direct reading instruments can be taken into the field to obtain data without extensive calibration procedures. Additional levels of quantification can be obtained with transportable instruments such as gas chromatographs (GC), x-ray fluorescence, or atomic adsorption devices. For these instruments, however, calibration using known standards must be completed prior to field use.

Conceptually, an analytical approach can be thought of as a large "inverted funnel" whereby large numbers of samples are analyzed quickly and cost effectively in the field, with succeedingly smaller numbers of samples analyzed further using successively more sophisticated procedures. The type and design of this analytical approach is determined by how the data will be used. By strategically selecting the samples analyzed at each level, a much higher degree of certainty can be obtained for the overall data set without sacrificing either the quantity of samples analyzed or the quality of data collected.

For example, consider a hazardous waste site where the soil is contaminated with volatile organic compounds (VOCs). For this example, the objectives of the sampling are determination of VOC concentrations at site boundaries and assessment of the direct contact threat. It is assumed that a photoionization detector will detect contaminants at the levels of concern for this example.

The analytical approach for this hypothetical situation is illustrated in Figure 4-3 and summarized below:

- Samples from all locations are analyzed in real time using photoionization field headspace techniques (Level I).
- A limited number of samples for which nothing was detected and all samples for which VOCs were detected are analyzed on-site using a portable gas chromatograph (Level II).


DATA QUALITY
DECREASING % OF SAMPLES ANALYZED
Level IV
Level III[1]
Level II
Level I
COST AND TURNAROUND TIME

[1] Although not applicable to the example situation, level III support is shown to indicate that this is a viable option for confirmatory analyses.

FIGURE 4-3
INTEGRATION OF ANALYTICAL SUPPORT LEVELS

- A number of samples are selected for analysis by CLP RAS (Level IV) for the Hazardous Substance List (HSL) compounds. All samples identified as critical data points are included. This step provides confirmation for all preceding work, including verification that indicator parameters are representative of contaminants of concern and are identified appropriately. The results of all split samples analyzed by different levels are interpreted for quality control purposes.

This approach can also be utilized in a time-phased manner, i.e., by using the results of an initial sampling round with a lower level of analysis to fine-tune the sampling approach for a subsequent sampling round using higher level(s) of analytical support. Another approach involves complete GC/MS analysis of the initial sampling round to identify the organic compounds present, followed by GC analysis of specific compounds of interest in later rounds. Gas chromatography with the appropriate detector can provide lower cost analyses, often with lower detection limits and higher precision and accuracy, than GC/MS. It is necessary, however, to verify by GC/MS that interfering compounds are not present.

### 4.5.2 RESOURCE CONSIDERATIONS

The resources available for performing a remedial action must be evaluated during the scoping process. Within Stage 2 of DQO development, the time required for obtaining data, the personnel resources and equipment required, and the costs for data collection must be evaluated. This evaluation is most effectively performed as sampling/analysis options are identified.

The cost for analytical support varies considerably depending on the type of analysis required. Schedule requirements dictating the need for rapid turnaround escalate analytical costs. The cost associated with obtaining samples must also be considered during the evaluation of sampling/analysis options. Cost savings can be achieved by performing multiple media sampling activities simultaneously (e.g., sample ground water and surface water during the same sampling event).

Critical path activities and technical staff resource needs should be identified early to facilitate efficient planning for the RI/FS.

## 4.6 REVIEW PARCC PARAMETER INFORMATION

The PARCC (precision, accuracy, representativeness, completeness, and comparability) parameters are indicators of data quality. Ideally, the end use of the measurement data should define the necessary PARCC parameters. In the ideal situation, numerical precision, accuracy, and completeness goals would be established and these goals would aid in selecting the measurement methods.

As noted earlier, RI/FS work does not fit this ideal situation. RI/FS sites are so different and information on overall measurements (sampling plus analysis) is so limited that it is not practical to set universal PARCC goals at this time. Rather, the historical precision and accuracy achieved by different analytical techniques should be reviewed to aid in selecting the most appropriate technique.

To indicate achievable precision and accuracy, tables in Appendix F present historical precision and accuracy information for analytical techniques classified by level. EPA will continue to make information of this type available so that a data base of numerical precision and accuracy requirements appropriate to different data uses will develop.

### 4.6.1 PRECISION

Precision measures the reproducibility of measurements under a given set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value.

Precision is usually stated in terms of standard deviation but other estimates such as the coefficient of variation (relative standard deviation), range (maximum value minus minimum value), and relative range are common.

The overall precision of measurement data is a mixture of sampling and analytical factors. Analytical precision is much easier to control and quantify than sampling precision. There are more historical data related to individual method performance and the "universe" is limited to the samples received in the laboratory. In contrast, sampling precision is unique to each site.

Sampling precision may be determined by collecting and analyzing collocated or field replicate samples and then creating and analyzing laboratory replicates from one or more of the field samples. The analytical results from the collocated or field replicate samples provide data on overall measurement precision; analysis results from the laboratory replicates provide data on analytical precision. Subtracting the analytical precision from the measurement precision defines the sampling precision.

### 4.6.2 ACCURACY

Accuracy measures the bias in a measurement system; it is difficult to measure for the entire data collection activity. Sources of error are the sampling process, field contamination, preservation, handling, sample matrix, sample preparation and analysis techniques. Sampling accuracy may be assessed by evaluating the results of field/trip blanks, analytical accuracy may be assessed through use of known and unknown QC samples and matrix spikes.

As an example of how the sampling process can affect accuracy, consider the collection of ground water samples for volatile organic analysis. In the actual sampling, some portion of the volatile components may be lost. There is no way to measure this loss easily. The sample could also be subjected to contamination from a wide range of sources in the field and laboratory. To check the system for contamination, trip and field blanks can be used.

### 4.6.3 REPRESENTATIVENESS

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition. Representativeness is a qualitative parameter which is most concerned with the proper design of the sampling program. The representativeness criterion is best satisfied by making certain that sampling locations are selected properly and a sufficient number of samples are collected.

Representativeness is addressed by describing sampling techniques and the rationale used to select sampling locations. Sampling locations can be biased (based on existing data, instrument surveys, observations, etc.) or unbiased (completely random or stratified-random approaches). Either way, the rationale used to determine sampling locations must be explicitly explained. If a sampling grid is being utilized, it should be shown on a map of the site. The type of sample, such as a grab or composite sample, as well as the relevant standard operating procedure (SOP) for sample collection, should be specified.

An example of the way representativeness is ensured in a sampling program is the use of proper ground water sampling techniques. The SOPs for ground water sampling require that a well be purged a certain number of well volumes prior to sampling, to be certain that the sample is representative of the underlying aquifer at a point in time.

Representativeness can be assessed by the use of collocated samples. By definition, collocated samples are collected so that they are equally representative of a given point in space and time. In this way, they provide both precision and representativeness information.

### 4.6.4 COMPLETENESS

Completeness is defined as the percentage of measurements made which are judged to be valid measurements. The completeness goal is essentially the same for all data uses: that a sufficient amount of valid data be generated. It is important that critical samples are identified and plans made to achieve valid data for them.

Almost no historical data on the completeness achieved by individual methods exists. However, the CLP data has been found to be 80-85 percent complete on a nationwide basis. This can be extrapolated to indicate that Level III, IV and V analytical techniques will generate data that are approximately 80 percent complete. Levels I and II would be expected to have lower completeness levels. However, since they are on-site measurement techniques providing results in real-time or after minimal delay, invalid measurements can be repeated easily. Thus, a high degree of completeness can be achieved with these analytical levels.

### 4.6.5 COMPARABILITY

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Sample data should be comparable with other measurement data for similar samples and sample conditions. This goal is achieved through using standard techniques to collect and analyze representative samples and reporting analytical results in appropriate units. Comparability is limited to the other PARCC parameters because only when precision and accuracy are known can data sets be compared with confidence.

## 4.7 UTILIZING PARCC PARAMETER INFORMATION

In Stage 2 of the DQO process, the PARCC parameters should be considered in evaluating sampling and analysis options. To the extent possible, they should be defined as goals in the Stage 3 Data Collection Program.

Whenever measurement data are reviewed (in Stage 1 of the DQO process), the PARCC parameters which were achieved should be included in the review. The laboratory should provide numerical precision and accuracy data; Level II field analyses may also generate precison and accuracy data. Precision and accuracy data may be expressed in several ways and are best evaluated by an analytical chemist or a statistician. Since the precision data quantify the scatter of results about a mean value, a lower precison value means less scatter. Accuracy is most frequently reported as percent recovery, or percent bias. A 100 percent recovery indicates a completely accurate measurement; the closer the recovery is to 100 percent, the more accurate the measurement. Percent bias reports the difference of the result from the true value. A completely accurate measurement would have zero percent bias; the lower the percent bias, the more accurate the measurement.

The data user must keep the level of concern and the end use of the data in mind when reviewing precision and accuracy information. In some cases, even data of poor precision and/or accuracy may be useful. For example, if all the results are far above the level of concern, the precision and accuracy are much less important. However, close to the level of concern, precision and accuracy are quite important and should be carefully reviewed. If results have very good precision but poor accuracy, it may be acceptable to correct the reported results using the percent recovery or percent bias data. This judgment should be made by a data user with appropriate technical expertise.

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# 5.0 RI/FS DQO STAGE 3 DESIGN DATA COLLECTION PROGRAM

Stage 3 of the DQO process entails design of the detailed data collection program for the remedial action project. Through the process of addressing the elements identified in Stages 1 and 2, all the components required for completion of Stage 3 should be available. Stage 3 is outlined in Figure 5-1.

## 5.1 ASSEMBLE DATA COLLECTION COMPONENTS

During Stage 2, specific DQOs were developed by media or sampling activity. The intent of Stage 3 is to compile the information and DQOs developed for specific tasks into a comprehensive data collection program. A detailed list of all samples to be obtained should be assembled in a format which includes phase, media, sample type, number of samples, sample location, analytical methods, and QA/QC samples (type and number). In addition, a schedule for all sampling activities should be developed in bar chart or critical path method format.

## 5.2 DEVELOP DATA COLLECTION DOCUMENTATION

The output of the DQO process is a well defined sampling and analysis (S&A) plan with summary information provided in the work plan.

Data collection documentation requirements vary on a regional basis within the EPA. The DQO guidance provided in this document does not require the submittal of deliverables in addition to those already established in the regions. Rather, the DQO process provides a framework to ensure that all the pertinent issues related to the collection of data with known quality are addressed.

### 5.2.1 SAMPLING AND ANALYSIS PLANS

A written quality assurance/site sampling plan must be prepared for all remedial investigation activities which involve sampling. These plans should include the following:

- Description of the objectives of the sampling efforts, including the phase of the sampling and ultimate use of the data
- Specification of sampling protocol and procedures
- Specification of the types, locations, and frequency of samples to be taken

The S&A plan identifies the individuals responsible and the procedures for field activities and sample analyses. Quality assurance project plan (QAPjP) elements should be addressed in the S&A plan. The standard elements of a QAPjP are listed in Table 5-1. Details on preparation of QAPjPs are contained in Interim Guidelines and Specification for Preparing Quality Assurance Project Plans (EPA 1980).

The 16 points required in a QAPjP may be incorporated by reference if the information has been documented elsewhere. For example, if a project description (Item 3) is available in the work plan, it is acceptable to refer to this document rather than repeat the information. Quality assurance issues which are program wide in nature, such as internal quality control checks (Section 11), performance and system audits (Section 12), corrective action (Section 15) and quality assurance reports to management (Section 16), are generally specified in the quality assurance program plan (QAPP) and can be included in the QAPjP by reference.

Field investigation activities can be undertaken in a phased approach. Separate sampling/analysis plans may be prepared for the separate phases of a remedial investigation. For example, geophysical investigations may be performed to select locations for monitoring wells. In such a case, a sampling plan should be prepared for the geophysical investigations and, following evaluation of the data, a

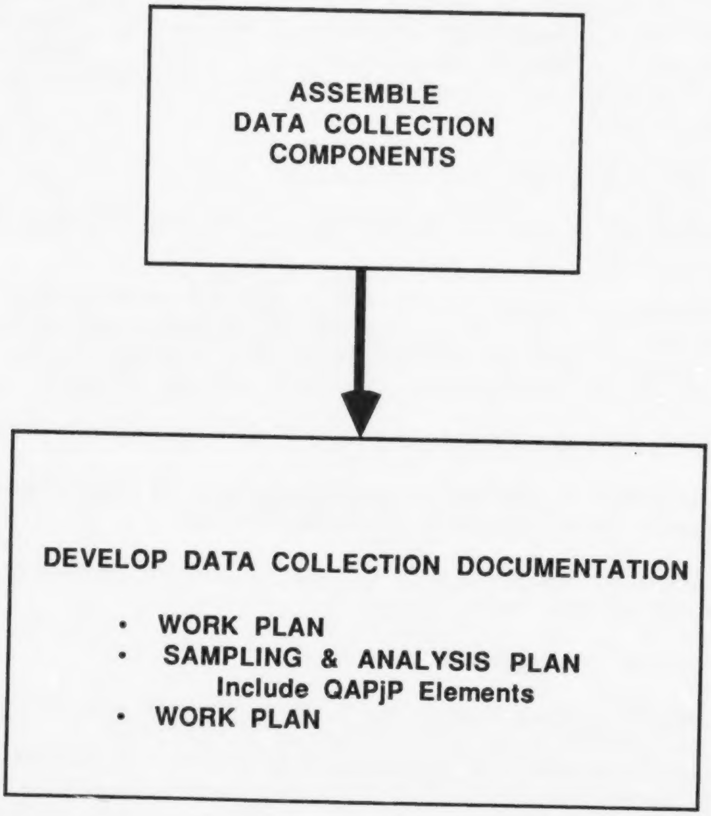
ASSEMBLE DATA COLLECTION COMPONENTS
DEVELOP DATA COLLECTION DOCUMENTATION
• WORK PLAN
• SAMPLING & ANALYSIS PLAN
Include QAPjP Elements
• WORK PLAN

FIGURE 5-1
STAGE 3 ELEMENTS
DESIGN DATA COLLECTION PROGRAM

## TABLE 5-1

## QUALITY ASSURANCE PROJECT PLAN ELEMENTS

| | |
|---|---|
| 1 | Title Page<br>Introduction |
| 2 | Table of Contents |
| 3 | Project Description |
| 4 | Project Organization |
| 5 | Quality Assurance Objectives for Data Measurement |
| 6 | Sampling Procedure |
| 7 | Sample and Document Custody Procedures |
| 8 | Calibration Procedures and Frequency |
| 9 | Analytical Procedures |
| 10 | Data Reduction, Validation and Reporting |
| 11 | Internal Quality Control Checks |
| 12 | Performance and System Audits |
| 13 | Preventive Maintenance |
| 14 | Data Measurement Assessment Procedures |
| 15 | Corrective Action |
| 16 | Quality Assurance Reports to Management |

separate plan should be developed for installation of the wells. Additional plans for the subsequent phases of a remedial investigation may be prepared at any time during the course of the project as the need for additional field investigation is identified.

### 5.2.2 WORK PLANS

Work plans define the scope of services, level-of-effort, costs, and schedule for performing the RI/FS; in general, the work plan describes what will be done, while the S&A plan and QAPjP describe how each task will be done. The scope of the sampling effort depends on the quality of existing data, an understanding of the site problems, identification and evaluation of feasible remedial actions, and enforcement needs.

The work plan provides the general description of the activities to be performed as part of the RI/FS. However, it does not contain the detailed description of how a sample is obtained or an analysis performed. This type of information is presented in the S&A plan. The level of detail to be included in the work plan for the RI phase is outlined below:

- How site mapping will be performed including survey limits, the scale of the plan to be produced, the horizontal and vertical control, and significant site features
- Number of individuals to be involved in each field sampling task and estimated duration in days
- Identification of geophysical survey areas or transects, soil boring and test pit locations on the map provided in the draft work plan
- Number of samples to be obtained in the field including blanks and duplicates and the location from which the samples will be obtained illustrated on a map included in the draft work plan
- List of analyses to be performed
- A general discussion of DQOs
- Identification of pilot or bench-scale studies that will be performed

This information is required as part of the work plan in order to establish a basis for the schedule and cost estimate. Work plans prepared for a phased RI approach should be specific for the initial phase, and general for subsequent phases, with subsequent phases well defined when the previous phase is completed.

### 5.2.3 ENFORCEMENT CONCERNS

All RI/FS activities should be conducted and documented such that sufficient data are collected to make sound decisions concerning remedial action selection. This applies to fund-lead, and potentially responsible party lead projects. The data collection and documentation activities should be similar for all types of RI/FSs. In other words, if enough data are collected using appropriate protocols, and the data are sufficiently valid upon which to base a remedial action decision, then the procedures and documentation should be sufficient to be admissible as evidence in litigation.

The guidelines outlined below should be followed to assure that data quality objectives are met:

- Appropriate plans (i.e., work plans, sampling and analysis plans, QAPjP) should be developed to document intentions.

- Field notebooks should be maintained to keep accurate records of sampling activities.
- Personnel should have appropriate experience or training.
- Chain of custody records must be kept for samples.
- Methods used for sampling and analysis should be valid from an engineering/scientific standpoint and be consistent with standard analytical procedures.
- Documentation should be sufficient to allow the persons involved in the site studies to reconstruct the work if necessary.
- EPA's or the state's responsibility from a QA/QC standpoint is to audit randomly some RI/FS field sampling, analysis (QA/QC) and data validation to confirm that procedures utilized were sufficient.

The above requirements pertain to civil cases only. Criminal cases will require additional documentation and/or materials. EPA counsel should be consulted in these cases.

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# APPENDIX A

# STATISTICAL CONSIDERATIONS

# APPENDIX A
# STATISTICAL CONSIDERATIONS

Statistical techniques should be used to evaluate environmental data and to assist in designing appropriate sampling plans based on the data. Statistical techniques should be applied during PA/SI, RI/FS, RD, and RA activities.

Statistical considerations come into play in Stages 1, 2, and 3 of the DQO process. In Stage 1 the existing data are compiled and evaluated and statistical techniques can be used to evaluate the comparability of different sets of existing data and to evaluate the need to obtain additional data. In Stage 2 data quality and quantity needs can be stated in terms of confidence limits or within other statistical framework. After Stage 3, statistics can be used to evaluate newly acquired data and to assess uncertainty in various decisions.

This appendix provides discussions of various statistical approaches which may be appropriate for remedial action programs. The discussions are based upon hypothetical scenarios which have or might occur at hazardous waste sites and links available statistical methods to potential applications. The scenarios presented are not the only situations in which statistics can be applied, but they provide an indication of the information that can be obtained from statistical methods.

The scenarios will be discussed in an intuitive fashion keeping the use of equations and rigorous statistical formalism to a minimum. Hopefully this approach will allow the reader without a strong background in mathematics to follow the discussion and grasp the important role which statistical methods can play during site investigation and remediation. Because of the decision to present this material in a somewhat simplified form, readers with advanced knowledge of statistics may believe that the topics are not treated in sufficient detail. These readers and others who wish to obtain additional information on the methods presented are referred to the list of references provided at the end of this section.

## A.1 CLASSICAL STATISTICS VERSUS GEOSTATISTICS

When applying statistical procedures there are essentially two possible families of procedures which can be applied. Classical statistical techniques, based on the concept of the random variable, have been applied with success for well over 100 years. Geostatistical techniques, based on the concept of the random function, were developed in the 1960's, but have been applied very successfully to data from such diverse fields as mining engineering, petroleum engineering, hydrogeology, soil science, and, recently, hazardous waste. The property of geostatistical procedures which makes them applicable in such a wide variety of fields is that geostatistical techniques utilize the location of the data and the size of the site in all calculations, whereas classical techniques ignore both of these important parameters. Because classical techniques ignore data location, the decision of which set of procedures should be applied to a data set is straightforward. If the locations of the data and the size of the site can be ignored, then classical techniques can be accurately applied; otherwise, geostatistical techniques should be applied.

In the following sections, applications of both classical and geostatistical procedures will be provided. These sections will provide a clear distinction between these methods and will indicate when each are appropriate.

## A.2 ACCURACY AND PRECISION OF ANALYTICAL PROCEDURES

The type of statistical information which most readers are likely to encounter is precision and accuracy data. This data accompanies the results from each case of samples sent to the CLP and most non CLP laboratories. Interpreting accuracy and precision information can be key in understanding the significance of the reported values and assessing the confidence associated with any RI decision.

Because of the importance of this information, detailed definitions of both accuracy and precision are provided. A short example is provided to illustrate the use of these parameters.

If analytical procedures were perfect, the reported analyte concentrations would always exactly equal the actual concentrations present in the sample. In reality, analytical procedures are not perfect, so the reported and actual concentrations are commonly not identical. The difference between the reported concentration and the actual concentration of a sample is the analytical error. Without knowledge of the potential magnitude of the analytical error it is impossible to judge the significance of a reported concentration. An example where knowledge of the analytical error is crucial is the decision to shut down a drinking water well when the reported concentration is below the action level. Although, in this case, the reported value is below the action level, the actual concentration might exceed the action level due to analytical error. Without knowledge of the likely magnitude of the analytical errors the decision maker has insufficient information to make a decision. If the likely magnitude of errors were known, the decision maker could examine the impacts and likelihood of an incorrect decision and could reach an informed, correct, decision. In this section a procedure for examining analytical errors and judging the significance of reported values will be discussed. These procedures are based solely on classical statistics.

### A.2.1 DEFINITION OF ANALYTICAL ERROR

There are many sources of error which can be introduced when obtaining a sample. Some of these sources are improper sampling procedures, contaminated sample containers and use of improperly decontaminated sampling equipment. These types of errors are separate from analytical error and are not considered here. Analytical error is taken as the error due solely to the analytical procedure. This error is measured by laboratory spikes and duplicate samples.

### A.2.2 DEFINITION OF ACCURACY AND PRECISION

Analytical procedures can introduce errors due to a wide variety of causes, some of which are described in Appendix B. It is impossible to deterministically predict the magnitude of each error, so accuracy and precision have been introduced to summarize the errors of an analytical procedure. An example will provide a means of introducing accuracy and precision. Suppose that a standard sample containing a known amount of an analyte is submitted to four different laboratories (Lab A, Lab B, Lab C, and Lab D), each using the same analytical procedure. Each laboratory analyzes ten[1] replicates of the sample. The following results are obtained.

Reported Concentration of Standard (ppm)

| | Laboratory | | | |
|---|---|---|---|---|
| Replicate | A | B | C | D |
| 1 | 10 | 13 | 10 | 4 |
| 2 | 10 | 12 | 14 | 14 |
| 3 | 10 | 12 | 6 | 15 |
| 4 | 12 | 11 | 8 | 1 |
| 5 | 9 | 14 | 12 | 1 |
| 6 | 8 | 12 | 7 | 6 |
| 7 | 13 | 11 | 11 | 1 |
| 8 | 11 | 12 | 5 | 14 |
| 9 | 12 | 13 | 15 | 11 |
| 10 | 10 | 12 | 10 | 15 |

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[1] Ten replicates were chosen only to illustrate the concepts of accuracy and precision. There is no implicit or explicit recommendation that each sample be analyzed 10 times to determine accuracy and precision.

The actual concentration of the standard is 10 ppm. The majority of people examining these results would conclude that laboratory A provides the "best" results. This conclusion is reached because laboratory A either reports 10 ppm or a value very close to 10 ppm for each replicate.

Presented with results for replicate analyses, the average person could qualitatively rank a set of laboratories; however, such a comparison is time consuming and ultimately not useful, since it is not quantitative. To make sense of replicate data it must be summarized in a meaningful way. Accuracy and precision provide a method of summarizing replicate data which allows different analytical procedures and different laboratories to be compared. Accuracy and precision also allow a determination of the significance of individual reported values. The accuracy and precision of common analytical methods are presented in Appendix C.

### A.2.3 ACCURACY

Intuitively it is desirable that, on average, the reported concentration equal the actual concentration present in a sample. That is, ideally the analytical method should not have any systematic errors. Accuracy measures the average or systematic error of a method. In the example of the four laboratories, accuracy can be defined as the difference between the average of the 10 reported values and the actual value (10 ppm). Performing this calculation, the following results are obtained:

| Lab | Average of 10 Replicates (ppm) | Average Error (ppm) |
|---|---|---|
| A | 10.5 | 0.5 |
| B | 12.2 | 2.2 |
| C | 9.8 | -0.2 |
| D | 8.2 | -1.8 |

These results show that, on average, laboratories A and C yield reported values which are very close to the actual or spiked value. Thus, laboratories A and C are more accurate than laboratories B and D.

Accuracy values can be presented in a variety of ways. The average error shown above is one way of presenting this information; however, more commonly accuracy is presented as percent bias or percent recovery. Percent bias is a standardized average error; that is, the average error divided by the actual or spiked concentration and converted to a percentage. For Lab A in the previous example, the percent bias is .5/10 = .05 or 5 percent since the actual concentration is 10 ppm. Percent bias is unitless so it allows the accuracy of analytical procedures to be compared easily.

Percent recovery provides the same information as percent bias. Since accuracy is often determined from spiked samples, laboratories commonly report accuracy in this form. Percent recovery is defined as:

$$\% \text{ Recovery} = \frac{R}{S} \times 100$$

where S = spiked concentration

R = reported concentration

Given this definition it can be shown that

$$\% \text{ bias} = \% \text{ recovery} - 100$$

For this example, the observed % bias and % recovery are:

| Lab | Percent Recovery | Percent Bias |
|---|---|---|
| A | 105 | 5 |
| B | 122 | 22 |
| C | 98 | -2 |
| D | 82 | -18 |

## A.2.4 PRECISION

Whereas accuracy measures the average properties of an analytical method, precision examines the spread of the reported values about their mean. The spread of reported values refers to how different the individual reported values are from the average reported value. Precision can thus be seen as a measure of the magnitude of the errors.

Precision can be measured in a variety of ways, each of which has its merits. A simple measure of precision is the variance. The sample variances, calculated using the standard formula for the sample variance, for the 10 replicate samples sent to the 4 previously discussed labs are as follows:

| Lab | Variance of the replicates |
|---|---|
| A | 2.3 |
| B | 0.8 |
| C | 11.1 |
| D | 38.4 |

These results indicate that Lab B is the most precise. This could be determined by examining the ten individual values reported by Lab B which are all extremely similar. The Lab D reported values are very dissimilar. This feature is expressed by a large variance of the replicates.

Laboratories commonly determine precision from duplicate samples; thus precision is usually expressed as relative percent difference (%RPD) or relative standard deviation (%RSD). These quantities are defined as follows.

$$\%\ \mathrm{RPD} = 100 \times 2\ \frac{|X_1 - X_2|}{(X_1 + X_2)}$$

where $X_1$ and $X_2$ are the reported concentrations for each duplicate sample

$$\%\ \mathrm{RSD} = (100/\sqrt{2}) \times [2|X_1 - X_2|/(X_1 + X_2)]$$

## A.2.5 SUMMARY OF ACCURACY AND PRECISION

Based on the definitions of accuracy and precision, the performance of each of the four laboratories can be summarized in relative terms.

| Lab | Accuracy | Precision |
|---|---|---|
| A | High | High |
| B | Low | Very High |
| C | High | Low |
| D | Low | Low |

From this summary, it appears that Lab A provides the most reliable values. Notice however, that although Lab B has low accuracy, its precision is very high. Thus, if the reported values are corrected for the systematic error introduced by the laboratory, Lab B is superior to Lab A. In other words, if 2.2 ppm (which is the absolute average error, as calculated previously) is added to each of the values reported by Lab B, the reported values will have both very high accuracy and precision. This example demonstrates that if the bias of an analytical method is known, it can be easily be removed; however, it is not possible to correct for low precision.

### A.2.6 USING ACCURACY AND PRECISION INFORMATION

The accuracy and precision of four laboratories have been determined for a specific analyte. This information can now be used in the DQO process. For the purpose of this example, assume that a drinking water sample is sent to a single laboratory. The sample will be analyzed for four suspected contaminants. The historical accuracy and precision of the analytical procedures are known for these four analytes. The action levels for the four contaminants are:

| Contaminant | Action Level |
|---|---|
| A | 12 |
| B | 10 |
| C | 15 |
| D | 15 |

The lab reported the following concentrations for the sample:

| Contaminant | Reported Concentration |
|---|---|
| A | 9.0 |
| B | 9.99 |
| C | 7.0 |
| D | 8.0 |

All analytes except contaminant B are reported at concentrations below the action levels. The reported concentration for contaminant B is almost exactly at the action level. Based on these results, the well water might be considered to be safe for drinking.

Accuracy and precision information, as found in Appendix F, can be used to determine the safety of the drinking water by determining the probability that the actual concentration of each analyte present in the sample exceeds the appropriate action level.

The first step is to correct for the bias of each analytical procedure. To correct for bias, divide the reported concentration by the average percent recovery which is determined from spiked samples analyzed with the present sample, or historical information. Note that systematic correction of reported values for bias is not recommended; however, it is performed in this example because it is assumed that the bias is well known[1]. The corrected values are presented below.

| Contaminant | Reported Concentration | Percent Recovery | Corrected Value |
|---|---|---|---|
| A | 9.0 | 105 | 8.6 |
| B | 9.99 | 122 | 8.2 |
| C | 7.0 | 98 | 7.2 |
| D | 8.0 | 82 | 9.8 |

The standard deviation, S, for the analytical procedures can be calculated from the percent relative standard deviation, percent RSD. The standard deviation (S) is calculated in the following table by multiplying the reported value by the percent RSD.

| Contaminant | Reported Concentration | %RSD | S |
|---|---|---|---|
| A | 9.0 | 14.5 | 1.3 |
| B | 9.99 | 7.5 | .75 |
| C | 7.0 | 34.0 | 2.4 |
| D | 8.0 | 75.6 | 6.0 |

A simple technique for presenting the uncertainty in analytic results is to present the probable range of values which might be expected from the analytical procedure. In a quality control chart, the probable range is usually ±3 standard deviations about the expected value, in our case the corrected value.

| Contaminant | Reported Concentration | Corrected Value | S | Action Level | Probable Range |
|---|---|---|---|---|---|
| A | 9.0 | 8.6 | 1.3 | 12 | (4.7,12.5) |
| B | 9.99 | 8.2 | .75 | 10 | (6.0,10.5) |
| C | 7.0 | 7.2 | 2.4 | 15 | ( 0 ,14.4) |
| D | 8.0 | 9.8 | 6.0 | 15 | ( 0 ,27.8) |

The upper limit of the probable range is

Corrected Value + 3 x Standard Deviation.

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[1] Correcting for bias in an analytical procedure should be done on a contaminant by contaminant basis, taking into account the nature of the media and the matrix being analyzed.

Note that only contaminant C has an upper limit which does not exceed the action levels. The upper limit for contaminants A and B just exceeds the action level, (12.5 vs. 12 and 10.5 vs. 10). Contaminant D's upper limit is well above its action level, even though its reported value is only 8.0.

If the distribution of reported values is assumed to be normal, the probability that the actual sample concentration exceeds the corresponding action level can be calculated.

Tables of the normal distribution are available in all statistics books. These tables give the probability of exceeding a series of standardized variables. To utilize these tables, the reported analytical values must be standardized. The standardization is

$$Z = \frac{X - X_c}{S}$$

where $Z$ = standardized value
$X$ = action level
$X_c$ = corrected reported concentration
$S$ = standard deviation of the analytic test.

The values $X$, $X_c$, and $S$ are known in this example and can be used to determine the probability of exceeding the action levels, $\Pr[X_c > \text{Action Level}]$.

| Contaminant | Reported Concentration | Action Level | Z | $\Pr[X_c > \text{A.L.}]$ |
|---|---|---|---|---|
| A | 9.0 | 12 | 2.6 | .005 |
| B | 9.99 | 10 | 2.4 | .008 |
| C | 7.0 | 15 | 3.3 | .001 |
| D | 8.0 | 15 | 0.87 | .19 |

These probability values indicate that by utilizing accuracy and precision information, the significance of the reported values can be assessed. Even though all the reported concentrations were below the action levels, further analysis demonstrates that contaminant D has a 19 percent chance of being greater than the action level of 15. Contaminant B, with a reported value at the action level, 9.99 vs. 10.0, has in actuality less than a 1 percent chance of exceeding the action level of 10.

The precision of the analytical procedure for analyte D is poor as expressed by its high percent RSD of 75.6 percent. Precision can be improved by analyzing sample replicates or splits. If the lab analyzed three splits, the percent RSD and standard deviation would have been reduced by 58 percent ($1/\sqrt{3}$). The new S would have been 3.5 (6x.58), and the new Z value 1.48. Thus, the new probability that contaminant D would exceed the action level of 15 is only 7 percent which could be an acceptable risk depending on the toxicity and health effects of contaminant D.

This simple example demonstrates the importance of accuracy and precision information and indicates the possible consequences of ignoring these data. Because of the importance of accuracy and precision information, Appendix F, which gives accuracy and precision data for many common analytical techniques, has been compiled. Decision makers are urged to examine this appendix and to utilize the information prior to reaching a decision.

## A.3 PROBABILITY OF LOCATING A CONTAMINATED ZONE

At sites or portions of sites where soil contamination is suspected but no definite sources have been identified, an objective of the remedial investigation might be to determine if soil contamination is present. Important decisions facing the site manager are how many samples must be taken to investigate the potentially contaminated area and where the samples will be located.

In certain situations geophysical surveys can be utilized in determining the location of contaminated zones. Geophysics can effectively be used to determine the locations of certain ground water plumes (such as hydrocarbon plumes) and concentrations of buried metallic objects (drums and tanks). The following discussion concerning the probability of locating a contaminated zone is applicable to geophysical methods as well as to standard sampling techniques.

The decision maker must determine, in Stages 1 and 2 of the DQO process, the acceptable probability of not finding an existing contaminated zone in the suspected area. For instance, it might be determined that a 20 percent chance of missing a 100-ft-by-100-ft contaminated zone is acceptable but only a 5 percent chance of missing a 200-ft-by-200-ft zone is acceptable. This probability value provides the basis for using statistics to determine how many samples are required. Statistical methods can be used to determine the number and location of data required to lower the probability of missing an existing contaminated zone to a value less than the acceptable predefined value. The acceptable probability of missing a contaminated zone must be established by the decision maker working in concert with the data users. Individuals involved in developing risk assessments may provide meaningful inputs into determination of the appropriate probability values to be utilized.

The statistical method applied in this instance involves geometric probabilities. That is, the probability of not identifying a contaminated zone is related to the area or volume of the contaminated zone and the spatial location of the samples. This method is not clearly a classical statistical or geostatistical procedure, it will be considered as a hybrid statistical method.

To apply this method, the following assumptions are required:

- The shape and size of the contaminated zone must be known at least approximately. This known shape will be termed the target.
- Any sample located within the contaminated zone will identify the contamination.

These assumptions are not severe and should be met in practice.

If, in addition to the above assumptions, data are located on a perfectly regular grid and the target is circular, the probability of hitting the target for a given grid size is given by the following (Gilbert 1982):

| Probability of a Hit | G/A |
|---|---|
| 0.8 | 1.13 |
| 0.9 | 1.01 |
| 0.95 | 0.94 |
| 0.99 | 0.86 |

where A is the diameter of the target and G is the linear grid spacing.

If data are not regularly located or the target is not circular, a simulation procedure is used.

The procedure used is hit or miss simulation involving the following steps:

- Simulate a contaminated zone or target.
- Randomly locate the target within the site.
- Determine if any sample locations fall within the boundaries of the target. If so score a hit, otherwise a miss.
- Simulate and randomly locate several hundred targets using a computer program and record the number of hits and misses.

The probability of locating the contaminated zone is equal to the total number of hits divided by the total number of simulations.

Figure A-1 illustrates the hit or miss approach for two simulated contaminated zones. The method is flexible so various different sample configurations and various different target sizes can be quickly examined. By varying the number of samples for a fixed target, the number of samples required to lower the risk of missing the contamination to an acceptable level can be determined. Thus, this method allows determination of both the number and location of samples necessary to satisfy DQOs.

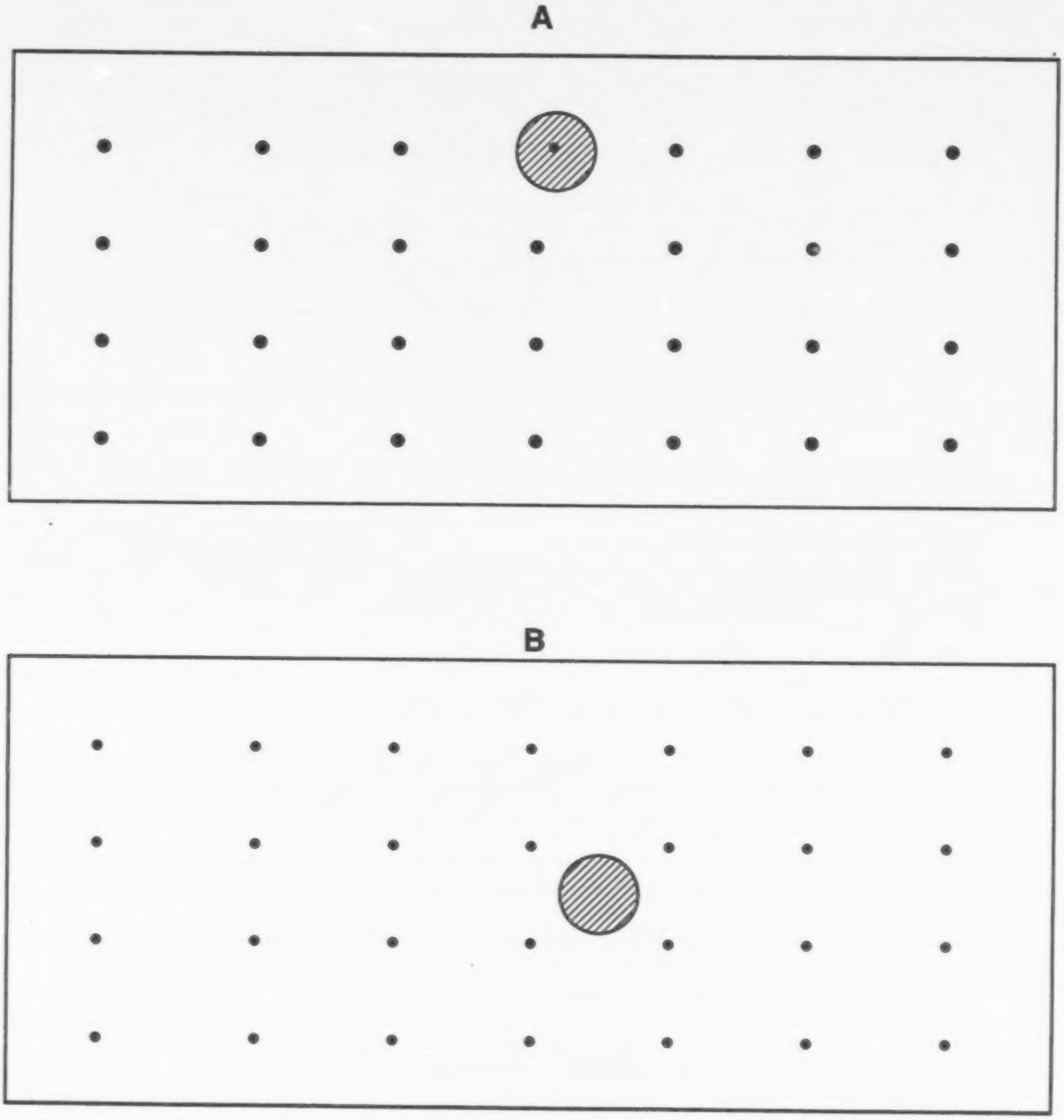
## A.4 CONFIDENCE LIMITS ON ESTIMATES OF MEAN CONTAMINATION

At sites where contamination is known to exist, a parameter of interest is the mean contaminant concentration over the contaminated area. Mean contaminant concentrations are important when evaluating contaminants contained within a confined area such as a lagoon. In this case, the mean contaminant concentration determines the total amount of contaminants contained in the lagoon. To assess various remedial alternatives it is important to know the maximum quantity of contaminants present in the lagoon. Confidence limits can be used to state the probable range of total contaminants contained in the lagoon.

Confidence limits can, theoretically, be placed on any quantity calculated from a data set. Perhaps the most useful quantity is the sample mean. When the sample mean is calculated from a set of data, it is unlikely that the actual or population mean will equal the sample mean. The sample mean for a fixed number of data is a random variable whose value will fluctuate depending on the specific data collected. Confidence intervals are a method of quantifying the likely range of fluctuation of the sample mean. Confidence intervals are defined as follows; if the 95 percent confidence interval is set for the sample mean after each repetition of an experiment and the experiment is performed 100 times, the population mean is expected to fall between confidence limits 95 times.

For example, 20 soil samples are collected at a site with known soil contamination. The sample mean is calculated from these samples and is determined to be 14 mg/kg of an analyte of interest. Furthermore, it is determined that the 95 percent confidence limits for this sample mean are 12 and 17 mg/kg. In this example, there is a 95 percent chance that the actual mean soil concentration falls between 12 and 17 mg/kg.

To determine a confidence interval the distribution of the sample mean must be known. To determine the distribution at least three quantities are required. These quantities are the estimated sample mean, the variance of the sample mean and the shape of its distribution. Both classical and geostatistical approaches can be used to determine these quantities. Each of these methods will be discussed individually; however, before proceeding it must be noted that neither of these methods can be applied without site-specific information.



NOTE: This figure illustrates two possible simulations of a circular target for a fixed set of data locations. The upper figure (a) illustrates a hit while the lower figure (b) illustrates a miss

A - 1
HIT & MISS EXAMPLE

### A.4.1 THE CLASSICAL STATISTICAL APPROACH

Classical statistical approaches assume that the distribution of the sample mean follows Student's t or, if more than 30 data are available, a normal distribution. This assumption is considered valid because of the power of the central limit theorem which states that regardless of the distribution of the data, the sample mean follows a normal distribution when sufficient data are obtained. The drawback of the classical statistics approach is that the variance of the sample mean is taken as the variance of the data divided by the number of the data available regardless of the location of the data or the size of the site.

Thus, when using classical statistics to determine a confidence interval for a sample mean based on 10 data, it does not matter whether the data are spread uniformly over the site or clustered in one corner; nor does it matter if the site covers 1/4 acre or 20 square miles. The confidence intervals in each of these cases will be identical.

Since all scientists and engineers working on hazardous waste sites realize that both data location and the size of the site are crucial factors in analyzing the significance of data, it is not logical to apply a procedure which does not account for these important factors. However, if in some specialized instance it is deemed that sample locations are not important, the classical statistical procedures based on the t statistic yield simple formulas for determining confidence intervals and data requirements. These formulas are provided in many references including EPA 1984 and EPA 1985.

### A.4.2 GEOSTATISTICAL APPROACH

Geostatistics, or more formally, the theory of regionalized variables, is similar to classical statistics in many ways. Most importantly, it differs with respect to basic assumptions regarding independence of the data. Classical statistics assumes that data are mutually independent, that is, that one data point is not related to another. Geostatistics recognizes that observed concentrations are governed by physical processes; thus, one particular point in space yields information concerning the expected contaminant level at a location 5 or 10 ft away from the sampled point. In statistical terms, these data are correlated in space. Geostatistical tools measure and exploit the correlation between data to estimate contaminant concentrations and determine the uncertainty associated with the estimate. In other words, geostatistical methods consider the location of data and the size of the site in any calculation.

Geostatistics can be used to determine the variance of errors associated with any weighted estimate of the sample mean. In particular, geostatistics can be used to determine the variance of errors associated with estimating the true mean contaminant concentration by the average of the available data. The detailed derivation of the methodfor determining confidence intervals is given by Journel and Huijbregts (1978). A brief discussion of the method is provided here.

An estimate of the true mean site contamination can be determined from an average of the available data. The estimate is not, in general, equal to the true mean so an error is made. The error of estimation is defined as the estimated mean less the true mean. The particular error observed is one realization of the error random variable. The variance of the error variable is unknown, but it is known that the mean of the error distribution is zero since only unbiased estimators will be used. The variance of the error distribution can be determined using geostatistics.

The variance estimate requires knowledge of the average correlation between the data and the average correlation between the data and the volume defining the site. Determination of these quantities requires a model of correlation at the site. This correlation model is provided by the experimental variogram determined from the data. The experimental variogram is defined as follows:

$$g(h) = \frac{1}{n(h)} \Sigma (z(x_i + h) - z(x_i))^2$$

Where: n(h) is the number of data separated by distance h

$z(x_i)$ is the contamination observed at location $x_i$

$z(x_i + h)$ is the contamination observed at location $x_i + h$

g(h) is the experimental variogram for distance h

By varying h, a model of the variogram versus h can be developed and applied to determine the variance of errors. An example of a variogram is provided in Section 5.5.3.2 of the DQO example document.

To this point, the mean and variance of the distribution of errors have been discussed. The remaining parameter of interest is the shape of the distribution of errors. As the number of data used to estimate the true mean increases, the distribution of errors becomes more and more like a normal distribution. This is not a theoretical result but an observation from practical applications. Given that the errors follow an approximately normal distribution, the confidence limits can be determined by the following procedure.

- Define the level of confidence required.
- Find the standard normal variate corresponding to this probability in a normal table.
- Apply the following formula:

$Z - ys < u < Z + ys$

Where: y is the standard normal variate corresponding to the confidence interval

Z is the sample mean

$s^2$ is the variance of errors determined by geostatistics

u is the true mean

The number of data used does not appear explicitly in this formula. However, as the number of data used increases, the estimation variance decreases and the confidence limits narrow. Geostatistics can be used to determine the number of data required to lower the confidence limits to any required values and furthermore can be used to determine the exact data locations which will cause the greatest reductions in the variance of errors. In this way, geostatistics can be used to determine optimal locations for additional data.

The geostatistical method of calculating confidence intervals is somewhat more complex than the classical method, but the geostatistical method is always more exact. It is impossible to provide a blanket statement concerning whether the classical procedure provides a more or less conservative solution because the geostatistical results depend on the site specific variogram model. It is possible to state, however, that when data are located on a regular grid and the spatial distribution of the variable of interest is isotropic, the classical procedure (t statistic) provides a conservative estimate of the size of the confidence interval. That is, the classical procedure will overestimate the number of data required to achieve a fixed level of confidence.

## A.5 LOCAL ESTIMATION OF CONTAMINATION

In many instances, the contamination at a particular point within the site is of interest. Determination of contaminant concentrations at unsampled locations is termed local estimation. For example, consider a site with a known source of contamination. Available information indicates that contaminants are migrating toward the western edge of the site. An objective of the RI might be to determine the western extent of contaminant migration. Geostatistics can be used to determine the likely extent of contamination. This information will greatly aid in choosing data locations.

A second example where local estimation is important is in determining optimal contours for a variable. For instance, in many enforcement cases an accurate determination of the ground water gradient is required to correctly identify potentially responsible parties. Water levels are measured in wells which are separated by varying distances. The heads between wells must be obtained. To ensure that the estimated heads and associated contour lines are as accurate as possible the heads at unsampled points should be estimated optimally using geostatistics.

Geostatistics can be used to address problems presented in the previous scenarios. The geostatistical technique which will be applied is known as kriging. Kriging, which is similar to multiple regression, determines an optimal estimate of a variable at any particular location in space. Associated with this estimate is a measure of uncertainty known as the kriging variance. To apply kriging, a model of the correlation between data is required. This model is obtained by modeling the experimental variogram of the data.

An example of the use of kriging to optimally estimate the concentration of lead in soil surrounding a smelter is shown in Figure A-2.

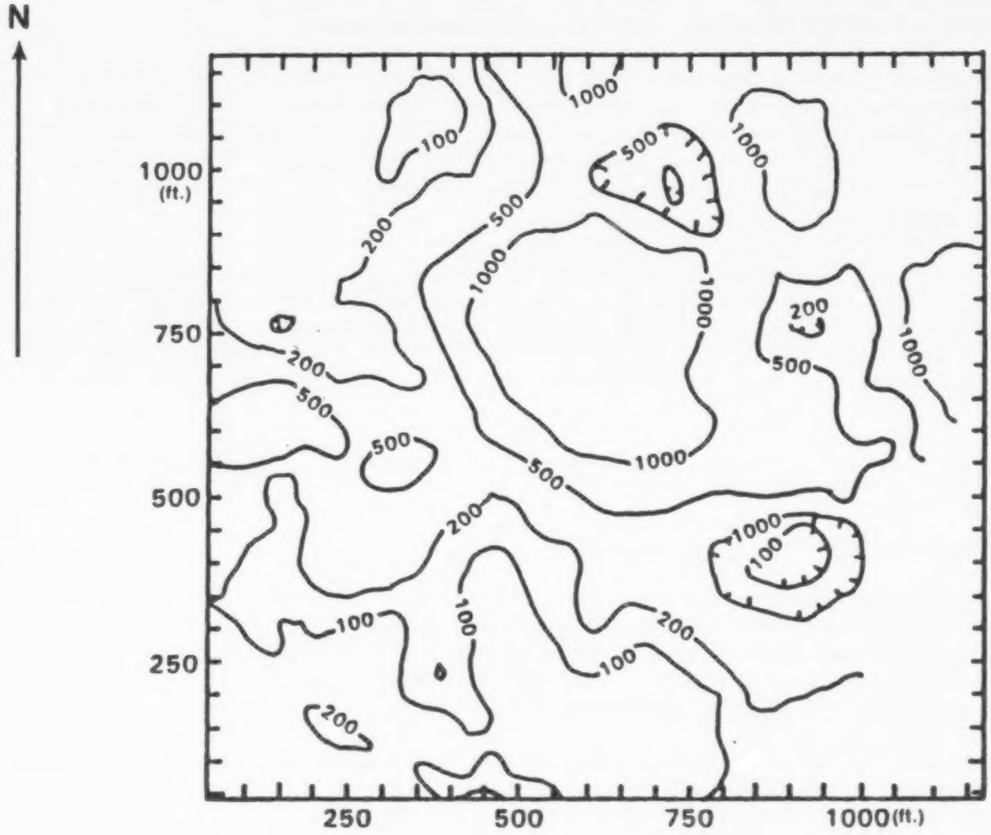
## A.6 LOCAL ESTIMATION OF PROBABILITY

At soil contamination sites where a fixed cleanup criterion has been set, geostatistics can be used to estimate the risk associated with not removing any particular quantity of soil. Geostatistics can be used to quantify the probability of exceeding this criteria and to develop probability contour maps. This map may be used in conjunction with the acceptable uncertainty determined during Stages 1 and 2 of the DQO process to define what volume of soil must be removed.

To determine the probability of exceeding a given value at an unsampled point it is necessary to estimate the entire contaminant distribution at that point. Given this distribution, the probability that the contaminant concentration exceeds any value of interest can be determined.

An example of a probability map is provided in Figure A-3. In this example, lead contamination has been found in soil surrounding a lead smelter. It has been determined that all soil in excess of 1000 ppm will be removed as part of the remedial action. The probability map gives the likelihood of exceeding 1000 ppm at each point in the site. If, through the DQO process, 30 percent had been determined as an acceptable probability of exceeding 1000 ppm, then all soil within the 30 percent contour would be removed. The remaining soil would have, at most, a 30 percent chance of exceeding 1000 ppm. If a different acceptable probability was defined, the volume of soil removed would be defined by the particular contour. This method provides an objective method for determining the volume of soil to be removed.

Techniques for estimating local probability distributions include indicator kriging, probability kriging, and multivariate gaussian kriging. (Journel 1983; Sullivan 1984; Verly 1983; and Isaakes 1983). These techniques are known as non-linear estimators and are related to but are more complex than kriging. These estimators require an accurate and detailed model of the correlation structure of the data to be effective.


N
1000 (ft.)
750
500
250
250
500
750
1000 (ft.)
100
200
500
1000
1000
500
1000
1000
1000
200
500
1000
200
500
500
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1000
200
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100
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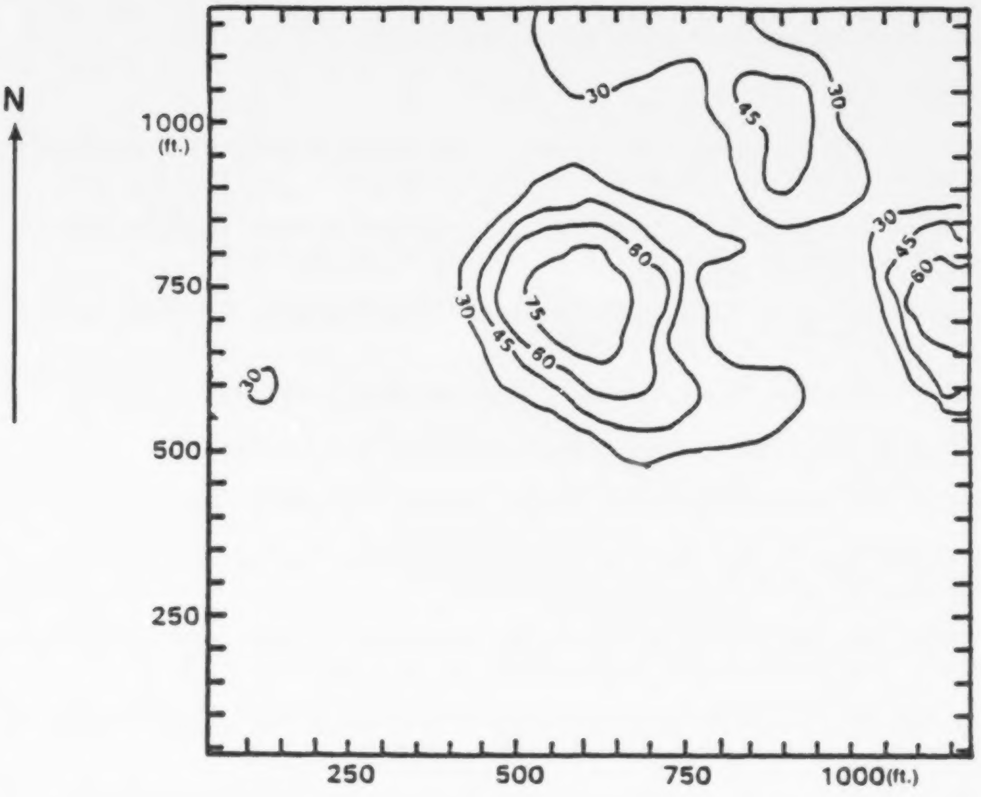
200
100
200

Note: Contour map of lead concentration in soil surrounding a smelter. Contours are based on estimates of soil lead concentration (in ppm) determined by kriging.

**A-2**
**EXAMPLE OF KRIGING**


N
1000
(ft.)
750
500
250
30
30
45
30
60
75
30
45
60
30
45
60
30
250
500
750
1000(ft.)

NOTE: Probabilities of exceeding 1000 ppm soil lead concentration near a smelter. Material with probabilities exceeding the acceptable risk defined in the DQO process will be removed as part of the remedial action.

**A-3**
**PROBABILITY MAP**

An important feature of non-linear estimators is that any uncertainty in the data values stemming from laboratory or sampling errors can easily be incorporated into the estimate. Since non-linear estimators can be used to estimate the mean or variance at a point or over a region, these techniques provide a means of including uncertainty in any regional or local estimate of the mean. The uncertainty associated with these estimates will include the uncertainity present in the data.

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# APPENDIX B

# ANALYTICAL CONSIDERATIONS

# APPENDIX B
# ANALYTICAL CONSIDERATIONS

Analytical methods must be evaluated during the development of site specific data quality objectives. The parameters for which the analytical method is valid, its limitations, and any special considerations (such as sample preparation) which will affect data quality must be understood in order to select appropriate analytical methods for specific uses.

This section provides an overview of the analytical considerations which should be taken into account during DQO development. Analytical considerations must be evaluated concurrently with statistical and sampling considerations in order to ensure that established DQOs can be attained.

## B.1 ANALYTICAL SUPPORT LEVELS

The analytical options available to support data collection activities are presented in five general levels. These levels are distinguished by the types of technology and documentation used, and their degree of sophistication as follows:

- LEVEL V - Non-standard methods. Analyses which may require method modification and/or development. CLP Special Analytical Services (SAS) are considered Level V.
- LEVEL IV - CLP Routine Analytical Services (RAS). This level is characterized by rigorous QA/QC protocols and documentation and provides qualitative and quantitative analytical data. Some regions have obtained similar support via their own regional laboratories, university laboratories, or other commercial laboratories.
- LEVEL III - Laboratory analysis using methods other than the CLP RAS. This level is used primarily in support of engineering studies using standard EPA approved procedures. Some procedures may be equivalent to CLP RAS, without the CLP requirements for documentation.
- LEVEL II - Field analysis. This level is characterized by the use of portable analytical instruments which can be used on-site, or in mobile laboratories stationed near a site (close-support labs). Depending upon the types of contaminants, sample matrix, and personnel skills, qualitative and quantitative data can be obtained.
- LEVEL I - Field screening. This level is characterized by the use of portable instruments which can provide real-time data to assist in the optimization of sampling point locations and for health and safety support. Data can be generated regarding the presence or absence of certain contaminants (especially volatiles) at sampling locations.

Table B-1 provides a summary of the analytical levels, their applicability, and limitations. Within each level, different procedures may be used to produce different quality data to some extent. For example, Level II encompasses both mobile laboratory procedures and less sophisticated "tailgate" operations which may produce data of different quality.

### B.1.1 LEVEL V ANALYTICAL SUPPORT - NON-STANDARD METHODS

The objective of non-standard analytical support is to provide the RI/FS process with data that cannot be obtained through standard avenues of analytical support. Analytical support of this type may involve the research, development and documentation of a method, or more typically, the modification of an existing method. EMSL-LV should be consulted for protocol availability, modification, or development. Level V methods are available through CLP Special Analytical Services (SAS), university laboratories, commercial laboratories, National Enforcement Investigation Center, and Environmental Services Division. Not all SAS analyses are non-standard; they may just not be part of CLP protocols.

TABLE B-1 SUMMARY OF ANALYTICAL LEVELS FOR RI/FS

| Option | Type of Analysis | Uses | Limitations |
|---|---|---|---|
| Level V | - Non-convential parameters<br>- Method-specific detection limits<br>- Modification of existing methods<br>- Appendix 8 parameters<br>- TIC | - Confirmational<br>- Toxicology<br>- Site-specific conditions/parameters<br>- RCRA compliance | - Requires method development/modification<br>- Mechanism to obtain services requires special leadtime<br>- Calibration standards may not be readily available |
| Level IV | - HSL organics/inorganics by GC/MS; AA; ICP. | - Confirmational<br>- Toxicology<br>- All other program activities | - Tentative identification of non-HSL parameters<br>- Some time is Required for validation of packages |
| Level III | - Organics/inorganics using EPA procedures other than RAS can be analyte-specific<br>- RCRA characteristic tests | - Confirmational but with less documentation<br>- Presence or absence of contaminants<br>- Engineering uses<br>- Screening | - Methods may vary |
| Level II | - Variety of organics by GC; inorganics by AA; XRF<br>- Tentative ID; analyte-specific<br>- Detection limits vary from low ppm to low ppb<br>- Portable/mobile instrumentation | - Presence or absence of contaminants<br>- Relative concentrations<br>- Engineering<br>- Screening | - Tentative ID<br>- Techniques/instruments limited |
| Level I | - Total organic vapor detection using portable instruments<br>- pH, conductivity, salinity, DO | - Assist in identifying sample locations<br>- Field screening<br>- Health and safety | - Instruments respond to naturally-occurring compounds |

TABLE B-1 SUMMARY OF ANALYTICAL LEVELS FOR RI/FS
(continued)

| Option | Data Quality | Cost | Time |
|---|---|---|---|
| Level V | - Method-specific | - Initially high, if method development is required. | - Entries refer to all types of analysis listed. No specific time/cost requirements can be specified. In general the time frame can range from a few weeks to significantly longer if method development is needed. |
| Level IV | - Rigorous QA/QC<br>- Standard methods | - $1,000/Sample for organics<br>- $200/Sample for metals | - Contractually, 30-40 days<br>- Shorter turnaround time possible through SAS request |
| Level III | - Similar detection limits to CLP<br>- Less rigorous QA/QC | - $960/Sample for organics<br>- $200/Sample for metals | - 14 days, but can vary based on contract requirements. |
| Level II | - Dependent on QA/QC steps employed<br>- Data typically reported in concentration ranges | - $15-40/Sample | - Real-time to several hours |
| Level I | - If instruments calibrated and data interpreted correctly, can provide indication of contamination | - Negligible, if capital costs excluded | - Real-time |

The analysis of samples for the RCRA modified Appendix VIII list of contaminants could currently be considered a Level V application. The modified Appendix VIII list contains 92 organic compounds that are not a part of the Hazardous Substances List (HSL) and therefore are not normally tested for on samples obtained from CERCLA sites. Appendix D of this document contains tables from a preliminary feasibility study performed to address the applicability of using or modifying existing analytical procedures for Appendix VIII analysis.

Level V poses limitations to implementation because the amount of lead-time for start-up may be significant, and the analyses may be "one-of-a-kind" applications of the method, resulting in a lack of comparability of the data. The unit costs for Level V sample analysis are dependent on the analysis requested. Generally, initial unit costs will be high, reflecting the costs of becoming familiar with the method. If the method is used for other projects or sites, unit costs may decrease with the demand, and the method may become standard. The amount of documentation available for Level V analytical support will vary depending on the sophistication of the technology used. If method development is required, this information should be requested and reviewed by the user.

Accuracy and precision information is generally not available for Level V. Thus, when level V methods are used, the number of duplicate and spiked samples must be increased to allow a determination of the accuracy and precision of the method.

### B.1.2 LEVEL IV ANALYTICAL SUPPORT - CONTRACT LABORATORY PROGRAM (CLP) ROUTINE ANALYTICAL SERVICES (RAS)

The CLP RAS provides for analyses of all types of media for Hazardous Substance List (HSL) organic compounds and priority pollutant inorganic compounds. (CLP RAS does not provide biota and air media [adsorption tube] analyses.) These services are available through CLP RAS and regional EPA ESD laboratories. Level IV analyses are currently used for most RI/FS activities. However, the use of level IV data may not be required for many RI/FS purposes. Level IV analyses are typically used for confirmation of lower level data, risk assessment, and to obtain highly documented data.

CLP RAS generated data have the following properties:

- Confirmed identification and quantitation of compounds (for HSL parameters only unless otherwise specified) to the detection specified in the IFB.
- Tentative identification of a contractually-specified number (30) of non-HSL parameters.
- Sufficient documentation to allow qualified personnel to review and evaluate data quality.
- Uniform methods of analysis activities.
- Detection limits may not be sufficient for toxicological evaluations
- CLP support is one of the most expensive routine analytical services available to the Superfund program, (e.g., RAS for organics is about $1,000/sample. RAS for inorganic is about $200/sample).
- RAS is contractually operating on a 30-40 day turnaround although delays can occur. Since demands fluctuate, space may be limited at times for the Superfund program. In addition, data validation usually takes 3-4 weeks after data is received.

The CLP RAS is very specific concerning the documentation that is supplied with every data package. The RAS deliverables package contains information on initial and continuing calibration, GC/MS tuning, surrogate percent recovery, and matrix spike duplicates. In addition, hard copies are provided of reconstruction ion chromatograms, GC chromatograms, and spectra for every sample and every blank, standard, or spike run with a particular set of samples. Documentation is also provided for blank analyses, internal chain of custody and holding times.

The bias and precision of CLP analytical procedures can be assessed by examining the performance of the laboratory in analyzing matrix spikes. However, an indication of the performance of the laboratory is also provided by the results of quarterly laboratory performance evaluation samples. These evaluation samples are submitted blind so the laboratory has no indication of the actual contaminant value. In contrast, the laboratory knows the exact concentration of a matrix spike.

Historical CLP precision and accuracy data classified by media are presented in Appendix F as Level IV. Each table is footnoted to show the source of the precision and accuracy data and, to the extent possible, the type of QC samples used, the numbers of data points, etc. Contract required detection limits are presented in Appendix H.

### B.1.3 LEVEL III ANALYTICAL SUPPORT - LABORATORY ANALYSIS

Level III analytical support is designed to provide laboratory analysis using standard EPA approved procedures other than current CLP RAS. This level is used to obtain similar analysis with less documentation.

Generally the analyses performed using Level III techniques are designed to provide confirmed identification and quantification of organic and inorganic compounds in water, sediment, and soil samples. These analyses are available through commercial laboratories, ESD, CLP SAS, and the CLP screening service (in development).

Level III provides data for site characterizations, environmental monitoring, confirmation of field data and to support engineering studies (e.g., design, modeling, and pilot/bench studies). In specific cases, Level III analyses can also provide data for risk assessment requirements.

Level III laboratory analysis provides the following:

- Data to support engineering design parameters
- Data for use in evaluating the site for further action, e.g., to determine extent of environmental contamination
- Data for use in risk assessments
- Rapid turnaround of data may be available
- Detection limits for presence or absence of compounds comparable to Level IV
- Costs range from about $200/sample for inorganics to $960/sample, for organics analysis. Turnaround time for Level III laboratory analysis for organics is expected to be about 14-21 days.

Level III protocols all have built-in QA/QC, including calibration runs, surrogate standards, etc. External QA, which is also used for the CLP, is employed in the form of trip blanks, replicate and duplicate samples, and blind spikes submitted with the samples.

The type of laboratory support available under Level III ranges in sophistication from GC/MS instrumentation to the measurement of water quality parameters. The type and amount of documentation available depends on the type of analysis requested. Data users should review a sample report issued by the laboratory for the analysis requested to determine if the degree of documentation supplied is adequate or whether additional information must be requested. If the documentation is sufficient, Level III could save time and cost.

Accuracy, precision and MDL information that is considered representative of this level of analytical support was compiled from SW-846. This information is provided in Appendix F. These procedures are applicable for all sample matrices; however, the SW 846 information presented was derived from the analysis of water and wastewater samples and performance evaluation standards. Therefore, the criteria specified in this table should be considered as "best case" information when non-aqueous media samples are analyzed. Also, these data are presented irrespective of the sample pretreatment or preconcentration techniques used. These techniques may include liquid-liquid extraction (3520), acid/base-neutral clean-up extraction (3530), soxhlet extraction (3540), sonication extraction (3550), headspace (5020), and purge and trap (5030). They are used in conjunction with the analytical procedures presented in SW 846.

### B.1.4 LEVEL II ANALYTICAL SUPPORT - FIELD ANALYSIS

Level II analytical support is designed to provide real-time data for ongoing field activities or when initial data will provide the basis for seeking laboratory analytical support. Level II analysis can also be utilized effectively when a phased approach is used for field sampling. In a phased sampling effort, the results of the first phase guide the development of subsequent phases, and thus, real-time data are important.

Field analysis involves the use of portable or transportable instruments which are based at or near a sampling site. Field analysis should not be confused with the process of obtaining total organic readings using portable meters.

Field analysis can provide data from the analysis of air, soil and water samples for many Hazardous Substance List (HSL) organic compounds, including volatiles, base neutral acid (BNA) extractable organics, and pesticides/PCBs. Inorganic analysis can also be conducted using portable atomic adsorption (AA) or other instruments.

Level II analyses is used for onsite, real-time screening, baseline data development, extent of contamination, and on-site remedial activities.

Level II - field analytical techniques provide the following:

- Rapidly available data for a variety of activities, including hydrogeologic investigations; cleanup operations; and health and safety.
- Detection limits for volatiles range from 0.5 ppb in air, 2-3 ppb in water, and 10 ppb for soil. Detection limits for PCBs in soil are about 1.0 ppm. Detection limits for extractable organic compounds analyzed in mobile labs are in the vicinity of 10 ppb.
- Special applications - e.g., vadose zone monitoring.
- Volatile organic data can be used as early indicators or tracers of off-site contaminant migration. Volatiles are the most mobile of organic contaminants in all media, and are typically found at some concentration at virtually all sites.

The ability to assess data quality for field activities is dependent upon the QA/QC steps taken in the process (e.g., documentation of blank injections, calibration standard runs, runs of qualitative standards between samples, etc.).

If capital expenditures are excluded, the costs of field analysis are in terms of personnel time in performing analyses, preparation/maintenance of equipment, etc. Per sample costs for mobilizing and staffing a field laboratory will decrease as the number of samples increases. Based on limited data from Region I FIT experience, per-sample costs for volatile and inorganic analyses are approximately $15. Per-sample costs for mobile laboratory analyses may approach $100. Depending on the type of analysis, time requirements per analysis range from 10 minutes to 1-2 hours.

Since Level II analyses are performed in the field, the amount and type of documentation available will vary with the type of analysis and the standard operating procedures used. Typically, a gas chromatograph operated in the field provides the bulk of the analytical support at this level. The documentation available utilizing this level of analytical support would consist of the output of an integrator or strip chart recorder for all samples, standards, and blanks analyzed. Field and analysis log books would also be a source of additional documentation.

Data generated by Level II analysis are typically confirmed by submitting some duplicate samples to CLP and/or a local laboratory. Factors to consider in choosing the number (or subset) of samples to be submitted for confirmational purposes include the following:

- Total number of samples taken (i.e., when only a few samples are taken, 100 percent confirmational analyses may be appropriate)
- Objective of sampling
- Data uses
- Method of analyses used

In general, confirmational samples should include a subset (or all) of designated critical samples, a subset of samples covering the entire range of identified concentrations, and a subset of samples near the (preliminary) action level and near the "0" concentration or not detectable range.

An additional factor to consider is the measured precision of the field instrument in use. When precision is high, fewer samples need to be confirmed; if precision is low, analysis should be suspended until the reason for the low precision is determined. A qualified chemist should be contacted for input on instrument calibration, and the utility of the analysis method with the specific field conditions.

The data base for documenting accuracy, precision and MDL information for Level II analyses is sparse. A number of factors have recently stimulated an interest in the development of Level II methods. This activity is centered primarily in various EPA Environmental Service Divisions (ESD) and remedial contractors. There are two ongoing projects expected to contribute significantly to the Level II data quality criteria data base. These projects are an EPA Headquarters-directed compilation of all Level II analytical methods currently used by Field Investigation Teams (FITs) and the operation of a mobile field analytical laboratory being directed by EPA/ESD in Region IV. The Region IV project, in particular, holds the promise of a significant contribution, since virtually all organic Hazardous Substance List (HSL) parameters are being analyzed for. As these data become available they will be incorporated into this document.

### B.1.5 LEVEL I ANALYTICAL SUPPORT - FIELD SCREENING

The objective of Level I analysis is to generate data which are generally used in refining sampling plans and determining the extent of contamination at this site. This type of support also provides real time data for health and safety purposes. Additional data which can effectively be obtained by Level I analyses include pH, conductivity, temperature, salinity, and dissolved oxygen.

Level I analyses are generally effective for total vapor readings using portable photoionization or flame ionization meters which respond to a variety of volatile inorganic and organic compounds. These analyses are available through ESD or remedial contractors.

Level I analysis provides data for onsite, real-time total vapor measurement, evaluation of existing conditions, samples location optimization, extent of contamination, and health and safety evaluations. Data generated from Level I support are generally considered qualitative in nature, although limited quantitative data can also be generated. Data generated from this type of analysis provide the following:

- Identification of soil, water, air and waste locations which have a high likelihood of showing contamination through subsequent analysis.
- Real-time data to be used for health and safety consideration during site reconnaissance and subsequent intrusive activities.
- Quantitative data if a contaminant is known and the instrument is calibrated to that substance.
- Presence or absence of contamination.

The most available form of documentation for this support level is the field operator log book. Sample identification, location, instrument reading, calibration and blank information is usually contained in the field log book. A hardcopy stripchart recorder output can be used with these instruments, but this is not common practice.

There are no data quality criteria specified for Level I, Field Screening Support, because this level is characterized by the use of hand-held instrumentation (PID, FID) which in general measure total organic vapor concentrations only, and as such, is not conducive to the generation of quantitative data. In specialized applications, FIDs can be calibrated to a specific compound and quantitative data can be obtained. Specific information regarding individual compound sensitivities and response factors can be obtained in the manufacturer's manual for specific instruments.

## B.2 ANALYTICAL FACTORS

Other factors which may affect development of DQOs include the following:

- Analytical quality control
- Instrumentation options
- Media variability
- Method detection limit
- Matrix effects
- Tentatively identified organic compounds
- Data qualifiers

### B.2.1 ANALYTICAL QUALITY CONTROL

The classification of analytical support into broad levels takes into account internal laboratory quality assurance/quality control (QA/QC) in a general manner only. Internal QA/QC refers to the surrogate and matrix spikes, method blanks, and duplicate/replicate runs, among other laboratory or field operation quality control. Within a given level of analytical support, there may be differences in the way individual laboratories or field operations approach internal QA/QC. For CLP Invitation for Bid (IFB) RAS analytical support, the procedures are standardized and contract-specified.

When evaluating laboratory QA/QC, it is important for the reviewer to keep the level of analytical support in perspective. These levels produce data of different quality and documentation and should be reviewed with this in mind. For example, it would be inappropriate to hold a screening laboratory to CLP RAS standards, or expect a field screening operation to have as rigorous QA/QC as a laboratory. Expectations such as these would be inconsistent with the concept of classifying analytical support by the quality of the data needed.

### B.2.2 INSTRUMENTATION OPTIONS

In some cases, the decision maker may have the option of choosing between similar analytical procedures for the analysis of a given parameter. Although each procedure is an EPA approved method, the reason for the equivalent procedures is that different analytical instrumentation is used for each method. Although the results obtained are equivalent, there can be subtle differences in the types of data produced by different instrumentation. When choosing analytical procedures, consideration should always be given to the instrumentation used in order to select the method that will best satisfy the stated analytical requirements. One of the many examples of equivalent procedures using different instrumentation for the analysis of the same parameters is the gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) procedures used for the analysis of organic compounds. An analytical chemist should be consulted to select the appropriate procedures for the specific problems encountered at the site.

### B.2.3 MEDIA VARIABILITY

Decision makers and data users should be aware that variability is introduced by the response of a given analytical technique or method to a given sample medium. Most of the analytical methods utilized in support of RI/FS activities were developed, at least originally, for aqueous samples and modified for use with other media with varying results. Also, the quality control data published for most analytical methods (concerning accuracy and precision information) were developed using aqueous samples. The performance criteria published may not totally apply to the use of the method with other sample media. When considering the analysis of source materials, leachate or other complex matrices, qualified analytical support personnel should be consulted to determine the most appropriate analytical approach.

### B.2.4 METHOD DETECTION LIMIT

Regardless of the specified method detection limit, the actual detection limit reported may be sample specific. This is especially true of samples having complex sample matrices (i.e., samples containing numerous analytes at widely-different concentration ranges). If the concentration of a particular sample constituent is so high that it requires dilution prior to analysis, the resulting detection limit for that sample will be raised by the dilution factor. For example, consider a sample being analyzed by GC/MS for volatile organics. The laboratory's normal detection limit for benzene by this method is 4.0 ug/1, but the sample may contain a high concentration of volatiles, and have to be diluted (say by at least a 1:10 ratio). The resulting detection limit for benzene will be 50.0 ug/1. In some cases, the laboratory can analyze the same sample twice to obtain the specified detection limit but this is not always possible, is not considered standard practice, and would have to be specified prior to sample submittal.

It is important to recognize that quantitative results reported at the detection limit may not be reliable. If the action level of a contaminant is 5.0 ug/l, an analytical method with a detection limit of 5.0 ug/l may not provide suitable data to meet the criteria. For example, the action level for trichloroethene (TCE) as defined the the Safe Drinking Water Act as a proposed Maximum Contaminant Level (MCL) is 5.0 ug/l. Analytical method 624 for volatile organics by GC/MS has a detection limit of 5.0 ug/l. Thus, method 624 may not be acceptable for this application. The magnitude of the action level and the detection limit must be considered in selecting a procedure.

### B.2.5 MATRIX EFFECTS

A matrix effect is a phenomenon that occurs when the sample composition interferes with the analysis of the analyte(s) of interest. This can bias the sample result either in a positive or in a negative way, with the negative bias being the most common.

The magnitude of a matrix effect is best assessed by the use of matrix spikes. Matrix spikes supply percentage recovery information which addresses the amount of bias present in the measurement system. This information can be used to adjust reported concentrations by the application of a correction factor based on percentage recovery. It is not recommended that sample values actually be adjusted for percent recovery unless a worst-case scenario is being developed.

### B.2.6 TENTATIVELY IDENTIFIED ORGANIC COMPOUND (TIC)

Under the CLP RAS procedures, 30 non-HSL peaks present in the reconstructed ion chromatogram are identified as tentatively identified compounds (TICs). Other laboratories may not address TICs or have different reporting criteria. If compounds of interest are tentatively identified by GC/MS and are high in spectra matching criteria (above 90 percent match) and above action levels, samples may be re-run against a standard in order to verify the compound's identity. Chromatographic retention time consideration is an important factor in assessing the probability of tentative identification reliability. Approaches for providing more reliable tentative identifications are under development.

### B.2.7 DATA QUALIFIERS

When analytical data are validated, the analytical results and the associated QA/QC information are reviewed using criteria specific to the analysis performed. This review can range from superficial to very rigorous, depending on the level of analytical support utilized and the type of technical review requested by the data user.

Data qualifiers are commonly used during the data validation process to classify sample data as to its conformance to QC requirements. The most common qualifiers are listed below:

- A - Acceptable
- J - Estimate, qualitatively correct but quantitatively suspect
- R - Reject, data not suitable for any purpose
- U - Not detected at a specified detection limit (e.g., 10U)

Sample data can be qualified with a "J" or "R" for many different reasons. Poor surrogate recovery, blank contamination, or calibration problems, among other things, can cause sample data to be qualified. Whenever sample data are qualified, the reasons for the qualification are stated in the data validation report. Data users are reminded that data validation is generally performed using strict analytical criteria which do not take the sampling activity's DQOs into account. Data users should request that the technical staff interpret the validation report according to the sampling activity's objectives and data uses. For example, data qualified with a "J" may be perfectly suitable for some data uses.

## B.3 ANALYTICAL ERROR

Analytical errors can be estimated for each compound or element of interest by method. Analytical error should be calculated for non-standard (Level V) or field (Level I) methods when possible.

In order to determine potential analytical errors, the accuracy and precision of the method must be known. The information required to develop meaningful calculations of analytical error include interlaboratory information for matrix spikes, surrogate recoveries, duplicated and blind performance evaluation standards for each compound analyzed for each analytical procedures as follows:

- Statistical Information - N, bias, RSD of percent recovery, concentration of spike, and concentration of analyte
- Matrix - air, aqueous, soil/sediment, leachate or source material
- Concentration Range - Liquids: 0-10 µg/l; 10-100 µg/l; 100-1000 µg/l or >1000 µg/l. Solids: <1 µg/kg; 10-1000 µg/kg; or >1000 µg/kg

If the above listed information is available, analytical errors could be predicted for the majority of analyses conducted in support of remedial actions.

For example; based on interlaboratory spike recoveries for benzene in ground water in the 0 to 10 ug/l concentration range using Method 624, the confidence interval at the 95 percent confidence level can be stated. This statement would be further qualified based on the number and types of laboratories, other types of performance evaluation criteria, matrix strength, and other pertinent analytical information. The detailed statistical information described above is not presently available. The accuracy and precision information that is available is given in Appendix F.

### B.3.1 LEVEL IV

Precision and bias data provided by the CLP RAS to be used in the estimation of analytical confidence limits include:

- Interlaboratory volatile organic matrix spike duplicate data for water and soil samples (N, percent RSD, percent RSD at 85th Percentile)
- "Interlaboratory" surrogate recovery data of generated volatile compounds from water and soil material (N, bias percent, percent RSD)
- Interlaboratory performance evaluation standard data for volatile and semi-volatile organic compounds in water and soil (N, bias percent, percent RSD).

In all cases, the data base has been sanitized, i.e., outliers have been removed. In the case of "interlaboratory" surrogate recoveries the data base should be considered interlaboratory in the classic sense - same sample submitted to a number of laboratories - but it is actually a close approximation. The same chemical surrogates are added to samples in individual laboratories but the laboratories are not recovering the surrogate from the same matrix. In addition, recovery data should be provided for the air, leachate and source material.

All of this information can still be used individually or in concert to develop uncertainty statements but with some inherent limitations.

- The interlaboratory matrix spike data as provided do not stratify the data with respect to concentration. Using these data requires the assumption that matrix recovery is a linear function of concentration.

- The "interlaboratory" surrogate recovery data are generally for one concentration range and as a result do not account for variability of accuracy as a function of concentration; assume that all analytes act as surrogate during the analytical process; and do not account for interlaboratory variations associated with different matrices.

- Interlaboratory performance evaluation standard data can probably be considered a "best case" for the development of uncertainty statements (actual samples would have a greater degree of uncertainty). The uncertainty associated with these data do not account for true sample matrix effects, or a wide range of analyte concentrations and as a result, the actual analytical uncertainty could only be worse than that estimated using this data set. It does have the advantage of being truly interlaboratory and blind (sample concentrations not known by participating laboratories) and should be a true measure of analytical uncertainty for the concentration range and matrix analyzed.

The best estimate of analytical uncertainty would be a composite of the uncertainty associated with matrix spike with the uncertainty associated with performance evaluation standards (interlaboratory performance only).

### B.3.2 LEVEL III

The available information to estimate uncertainty for Level III is the accuracy and precision statements included with the individual EPA approved procedures in SW-846. While this information is rarely stratified as to matrix and concentration, it could serve as a starting point (best case) from which the uncertainty associated with the actual analytical conditions could be estimated.

### B.3.3 LEVEL II

The most important factor that influences the uncertainty associated with Level II analyses is the skill of the analyst doing the work. Because the procedures are not formalized, a great deal of improvisation usually takes place. The inherent variability of the procedures themselves would make the development of a centralized quality assurance data base tenuous. The same reasoning would apply to making uncertainty predictions based on a centralized data base.

### B.3.4 LEVEL I

Level I analyses are qualitative, and therefore it is not possible to quantify the uncertainty in these methods.

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# APPENDIX C

# SAMPLING CONSIDERATIONS

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# SAMPLING CONSIDERATIONS

The error introduced by sampling procedures must be considered during the development of DQOs. Factors that can introduce sampling error include sampling/handling variability and the variability of contaminants as a function of location and time. The magnitude of each of these factors is largely site specific. The site specific nature of sampling errors distinguishes sampling from analytical errors, which are largely independent of site conditions.

This section focuses on factors that influence sampling errors and provides general guidance on sampling considerations to be evaluated during DQO development. It does not discuss specific sampling methods or provide strict guidelines for sampling design. The RPM and the site manager are responsible for ensuring that the appropriate technical experts are involved in development of the site-specific S&A plan.

## C.1 SAMPLING STRATEGY

In designing a sampling plan there are many factors which must be considered. Some of these factors such as the physical characteristics of the site (geology, hydrogeology, physiography) are unique to each site. However, there also are several general factors which must be considered for all sites. The general factors include decisions addressed during the DQO process such as:

- Will a phased approach be used?
- Will samples be collected for site characterization?
- Will samples be collected for confirmation purposes?
- Will grab or composite samples be collected?
- Will a grid system be used?

The importance of each of these factors varies from site to site, and therefore must be analyzed individually.

For sites at which a significant amount of data have been generated during preliminary assessments and site investigations, a focused approach to the RI can be developed. For sites for which little or no data are available or data are inconclusive, a broader approach to site investigations must be implemented. Data which are inconclusive or unvalidated may be appropriate for data uses requiring lower data quality (e.g., as indicators of areas requiring further study or confirmation).

## C.2 SAMPLING PROGRESSION

In the DQO process it may be necessary to identify a sampling approach before sufficient information has been gathered to use the statistical methods discussed in Appendix A. In these cases, it may be beneficial to use a phased data collection approach. In a phased approach, samples are collected in a series of independent sampling events. The first phase may be undertaken for site characterization purposes while subsequent phases use the information generated by earlier phases to fill in data gaps. If a mobile lab is utilized, phases may be continuous as results are analyzed and data gaps are identified and filled. The DQO process applies to each phase of an RI and for each sampling task. Initial sampling undertaken during the first phase may not yield specific information since little or no site specific data may be available. However, in subsequent phases of the RI more data will be available for decision making.

A phased approach to sampling is, in most cases, a cost effective method since areas of concern are identified in the early phases and are then targeted for additional sampling. When sampling is performed in only one phase, every conceivable target must be completely sampled. If one or several of the targets prove to be uncontaminated, a large number of unnecessary samples will have been taken.

Phased approaches must be developed on a site specific basis but generally will follow sequentially from general to progressively more detailed and sophisticated field sampling and analysis programs. The steps likely to be included in a phased sampling approach include the following:

- Review of existing information/data
- Remote sensing/geophysical techniques
- Field screening
- Intrusive sampling
- Pilot studies

### C.2.1 REVIEW OF EXISTING INFORMATION/DATA

All sources of available information should be obtained and reviewed during the initial stages of RI/FS project planning. It is especially important to obtain and review data from any previous investigations gathered in the National Priorities List (NPL) ranking process, FIT and/or TAT team investigations, and other data gathering activities conducted by the state or other parties. Detailed discussions of the various data sources which should be accessed during review of existing information are contained in the Remedial Investigation Guidance Document (EPA 1985).

### C.2.2 REMOTE SENSING/GEOPHYSICAL TECHNIQUES

Remote sensing is a term applied to methods used for the detection, recognition, or evaluation of objects or conditions by means of distant sensing or recording devices, including, but not limited to, aerial photography or satellite imagery. Kroeck and Shelton (1981) discuss the application of aerial photography to investigation of waste sites. Geophysical techniques are remote sensing methods used to characterize subsurface conditions without excavation. Information on the application of geophysical techniques to hazardous waste sites can be found in Benson, et. al. (1983).

Remote sensing/geophysical investigations should be used in the initial stages of RIs to provide an overall sense of the site environs (aerial photographs) and subsurface conditions. These techniques may also be used at later stages to provide a means for extrapolation of data obtained from disruptive techniques. For example, soil borings installed at a site may reveal the presence of a clay lens over a portion of a site which could affect ground water migration. Geophysical techniques could be used to provide information on subsurface conditions between the soil borings. In the absence of this information, an extrapolation of the soil strata between the borings may result in an erroneous interpretation of subsurface conditions.

### C.2.3 FIELD SCREENING

Proper field screening techniques can be instrumental in reducing the time it takes to perform an RI/FS, reduce costs, reduce "intrusive" sampling locations, and, in general, lead to more effective use of Level III and IV analyses.

Field screening is primarily used to provide indications of contamination at analytical Levels I and II. Thus, the decisions that will be based on the results of this type of sampling are in many cases yes/no type decisions. For instance, on the basis of soil gas screening it may be determined that contamination of a particular unconfined aquifer is indicated and further direct sampling is warranted.

### C.2.4 INTRUSIVE SAMPLING

Intrusive sampling includes all methods in which a physical sample from the media of concern is obtained. Intrusively obtained samples are used to obtain a numerical value for a physical or chemical measurement at a particular point. Intrusive sampling provides much more exact information concerning the concentration of contaminants or physical features than non-intrusive remote sensing or field screening techniques.

### C.2.5 PILOT STUDIES

Pilot studies are undertaken to obtain data to assess the applicability of various proposed alternatives for site remediation in a controlled manner. Pilot studies can also be undertaken to evaluate the effectiveness of various unit processes for treatment of a contaminant source at a site or for developing data needed to optimize system design and operation. The results of pilot treatability studies are used to develop design criteria; develop cost estimates; and to identify any special management or operational constraints which must be implemented in order to utilize the system under study. Analytical Levels II, III, IV, or V may apply to pilot studies.

## C.3 SOURCES OF VARIABILITY

To determine the uncertainty associated with a decision, all sources of variability must be taken into consideration. Important sources of variability are sampling/handling variability and the variability of contaminants as a function of location and time. Of these three sources, the variability of the contaminants as a function of location is expected to be the largest.

### C.3.1 SAMPLING/HANDLING VARIABILITY

Sampling/handling variability is defined as any variability introduced by the sampling and/or handling procedures, resulting in a contaminant concentration in the sample that is different than the concentration in the original media. Causes of sampling variability include incorrect sampling procedures and cross contamination. Since most of the causes of sampling/handling variability are related to errors in procedures, measurement of sampling variability is difficult. The magnitude of sampling variability can range from small to very large; however, if correct sampling and handling procedures are followed, sampling variability should be small compared to laboratory variability.

Sampling/handling variability can be reduced by training sampling personnel and performing all sampling activities in accordance with standard operating procedures (SOPs). SOPs are developed to ensure that any samples collected are representative of the undisturbed media of interest. By adhering to the SOPs, intra- and intersite variability for a given sampling method are greatly reduced or eliminated.

### C.3.2 TEMPORAL VARIABILITY

Many observed contaminant concentrations are dependent on time related variables such as the time of day or season of the year. The important variable linking concentration and time is often climatological (i.e., temperature or rainfall). Since the linking variables (temperature, for instance) follow cyclical patterns over a day or year, time dependent contaminant levels are also expected to follow cyclical patterns. To obtain representative samples of time related variables, it is important to identify the cyclical nature of the contaminant concentrations and to sample at various phases of the cycle to obtain a representative sample.

### C.3.3 SPATIAL VARIABILITY

Spatial variability describes the manner in which contaminants vary as a function of location. Although this source of variability is normally not considered explicitly, it is implicitly expected. The magnitude of the difference in contaminant concentrations in samples separated by a fixed distance is a measure of spatial variability. The level of spatial variability is site and contaminant specific. When spatial variability is high, a single sample is likely to be unrepresentative of the average contaminant concentration in the media surrounding the sample. Although it is important to recognize the nature of spatial variability at all times, it is crucial when the properties observed in a single sample will be extrapolated to the surrounding volume. Thus, when analyzing the results from a single ground water sample, spatial variability is not important; however, when attempting to determine the mean contaminant concentration over a portion of a site, or attempting to extrapolate or interpolate concentrations, spatial variability is important. Analysis of spatial variability is accomplished using geostatistics.

## C.4 SAMPLE TYPES

During the DQO development process the decision maker and data users must determine which types of samples should be obtained during the RI. The types of samples required to characterize a site may differ from those required to perform a pilot study. An evaluation of the intended use of the data must be undertaken in order to ensure that the type of sample obtained provides the necessary information to address the issues of concern. In determining the types of samples which should be obtained the following issues should be considered:

- Media vs. waste samples
- Grab vs. composite samples
- Filtered vs. unfiltered samples
- Biased vs. unbiased sampling

### C.4.1 MEDIA VS. WASTE SAMPLES

Media or environmental samples refer to sampling of air, water, soils, and other environmental media to determine the extent of contamination. Waste samples refer to the sampling of the actual wastes. Typically this will mean drums, impoundments, tanks, or other waste disposal areas.

Sampling will typically involve both investigation of general environmental media and specific waste accumulation areas. General questions regarding environmental media include:

- Which media are contaminated? (air, water, soil, ground water, biota)
- What is the average contamination?
- What is the total contamination? (mass, volume)
- What is the maximum contamination? (concentration)
- What area of the site is contaminated?
- What is the vertical and horizontal extent of contamination?

Waste samples are those collected from drums, tanks, lagoons, pits, waste piles, fresh spills, and other areas of waste accumulation. The specific area or container being sampled differs from the media samples in two ways: (1) the questions asked of the data and (2) the general characteristics of the materials being sampled. The most common questions are concerned with waste characterization:

- What compounds are present?
- Do these contaminants exceed any criteria or standards?

### C.4.2 COMPOSITE VS. GRAB SAMPLES

Grab samples are discrete aliquots which are representative of a specific location at a specific point in time. Composite samples represent the mixing of a number of grab samples and represent an average value. In the most common case, two or more grabs are added to the same container, mixed, and then a single aliquot is taken from the mixture. However, other forms of composite sampling might be from radiation badges or body samples for lead readings. In both these cases, the measurements would be over a number of hours and would not represent a single sampling location or time.

When developing or reviewing a sampling plan, it is important to consider the uses of grab and composite samples. Grab samples offer the most information regarding contaminant variability. Since compositing involves combining several grab samples, estimation of overall site properties using composites is less expensive than using grabs due to reduced analytical costs. However, compositing does not allow the spatial variability of data to be determined, so the confidence in a composite value may be impossible to determine. Composite samples should not be used when there is a potential risk of dangerous chemical reaction or when a measure of spatial variability is important.

### C.4.3 BIASED VS. UNBIASED SAMPLING

Biased sampling refers to a sampling scheme whose resulting data places emphasis on a single characteristic or factor of the problem. Unbiased sampling refers to sampling methods which allow for estimates to be drawn from the data which are representative of the population at large. These terms usually can be considered to be synonymous with random and non-random sampling.

Biased sampling is most common during the site investigation (SI) process. The purpose of the SI is to find out whether any contamination is present. Thus, these studies are typically conducted in ways that maximize the chance of analyzing samples which have contamination above a particular criteria. The use of direct reading instruments to screen samples is a good example of biased sampling. The samples which are finally analyzed using, for example, GC/MS will represent higher contamination than might exist overall at the site. This type of sampling is typically acceptable for the SI. In the RI/FS, this type of sampling may be acceptable in cases where design of a treatment system is dependent on the maximum treated load.

Unbiased sampling is performed by sampling on a regular grid. This type of sampling is unbiased because each sample is representative of an identical volume of the medium being sampled. This type of sampling is best for predicting overall site properties.

## C.5 SAMPLING PATTERNS

When acquiring data which will be used to make general inferences concerning site characteristics, it is important that samples provide complete coverage of the area of interest and that sample locations do not introduce bias. Complete coverage is necessary to ensure that no areas of contamination are missed. Bias in a data set causes the mean of the data to be systematically different from the true mean. Bias is caused by any systematic error in data location, such as clustering of data. When data are clustered (located close together) some small portions of the site are sampled more densely than the remainder of the site. The particular contaminant value observed in the densely sampled area will be over represented in the estimate of the sample mean. If, as is often the case, samples are clustered in highly contaminated areas, the mean site contaminant concentration will be overestimated.

Sampling patterns should be designed to minimize bias and provide complete site coverage. The best sampling pattern for accomplishing both of these goals is a regular grid. It can be shown theoretically (Ripley 1982), that data taken on a regular grid will yield a more precise estimate of the mean site contamination than data located according to any other procedure. This fact combined with the superior coverage and non-biased property of regular sampling make it the preferred sampling pattern when statistics will be applied.

The use of an unbiased approach during the initial sampling phases is recommended in order to ensure that no area of the site is overlooked in sampling. Subsequent sampling phases should incorporate the information resulting from the unbiased sampling which occurred during the initial phases. The data should be used to identify areas in which additional samples should be obtained and areas where no additional samples are required. Introduction of bias during subsequent phases may be justified in these instances.

### C.5.1 GRID SYSTEMS

Grid systems are used in developing systematic non-biased sampling plans in which samples are located at consistent distances from one another. The most elementary grid system is a straight line between two points on which regularly spaced sampling locations are noted. This type of one-dimensional sampling grid may be useful for sampling along a straight drainage ditch or other man-made feature. The majority of environmental sampling, however, requires a two-dimensional approach to sample location identification.

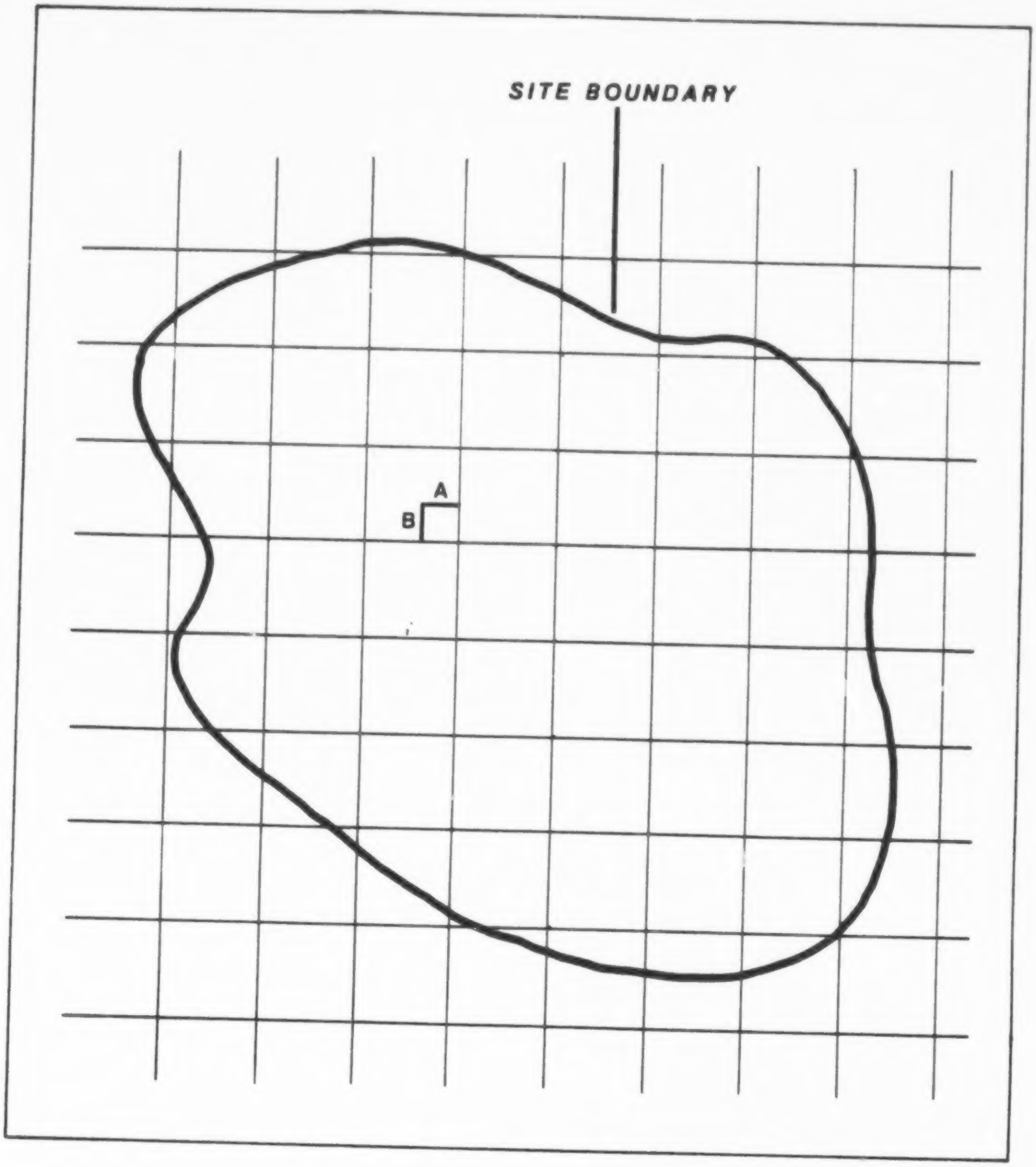
Figure C-1 presents a two dimensional square grid system for locating sampling points. The grid is comprised of equidistant parallel lines at right angles to each other. Figure C-2 presents a two dimensional triangular grid system comprised of equidistant parallel lines intersected by lines drawn at 60° from vertical in both directions. Sampling generally is undertaken at the intersection of the parallel lines which compose a grid, although other approaches such as sampling in the center of each grid box or obtaining a composite of samples within a grid box are also acceptable. It may be appropriate to modify the grid system to account for variations in concentration gradients as illustrated in Figure C-3.

### C.5.2 STRATIFICATION

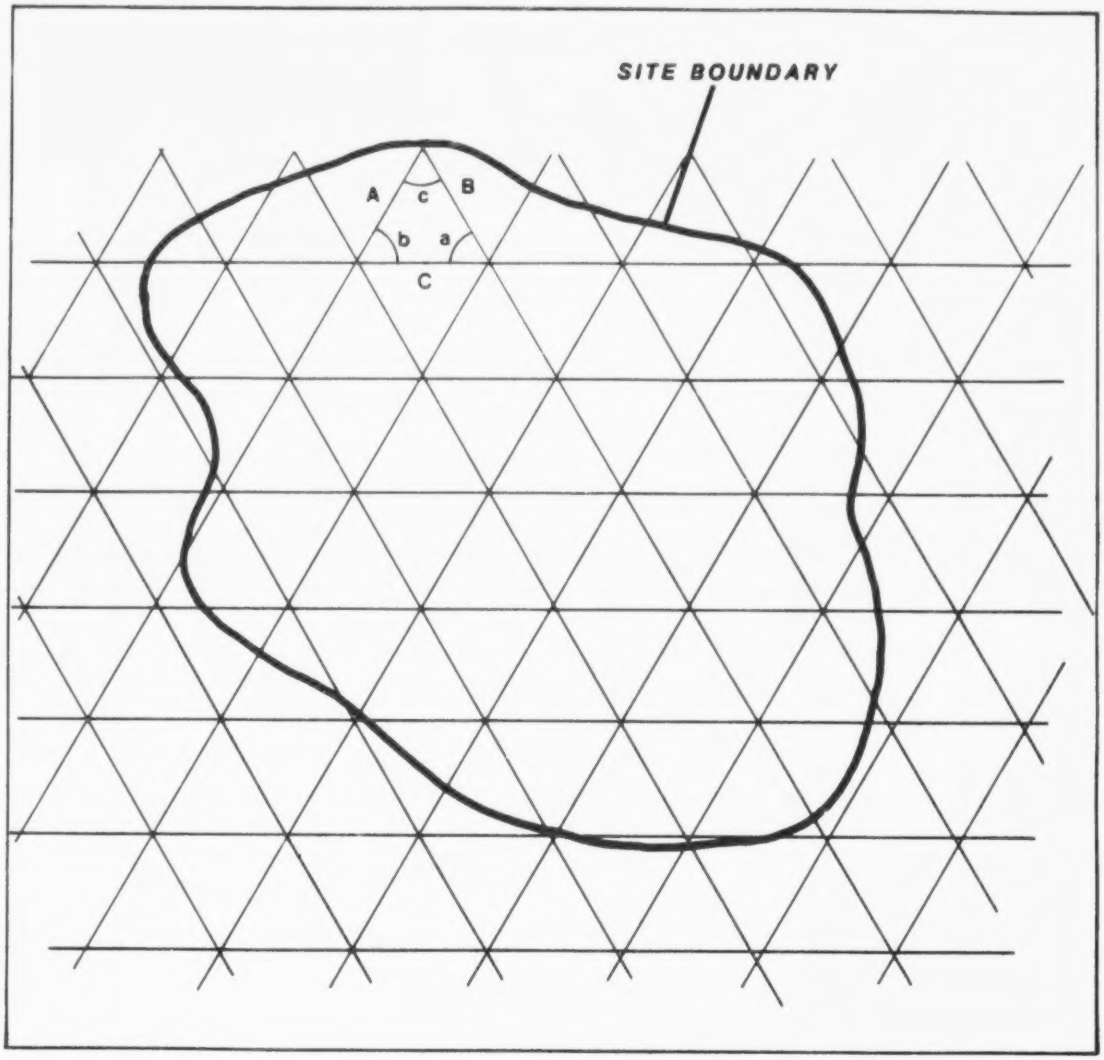
Stratification refers to the process of locating samples within distinct populations or strata. Commonly occurring strata are geological formations, soil horizons, and visually different areas of contamination. Typically, the number of samples taken within strata varied. For instance, initially, more samples should be taken from a visibly contaminated soil horizon than from a soil horizon which is not visibly contaminated. This approach needs to be used with caution and by experienced field personnel, as soil (and other media) which is not visibly contaminated could well be contaminated. By varying the number of samples in each strata based on existing information or information obtained in the field, the sampling program can concentrate on the most important aspects of the site. Stratification is thus a valuable method for conserving resources.

### C.5.3 GRID SPACING

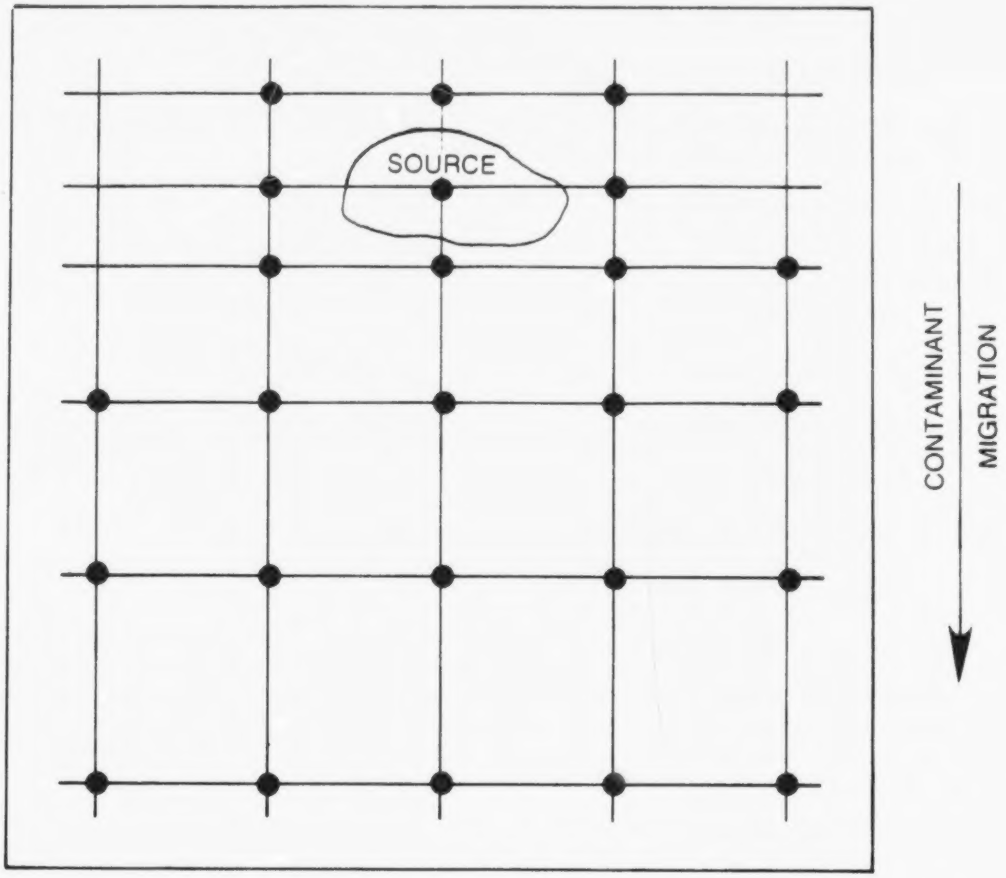
Spacings of grids are usually established to allow for sampling at each grid intersection. These alternative sampling approaches can be used when a low intensity investigation is used preliminary to more intensive sampling to be performed following review of the data. For example, a grid system may be placed over a site with grid lines spaced at 10-ft intervals. During the preliminary investigation samples may be obtained at every tenth intersection on every tenth grid line, thereby resulting in


SITE BOUNDARY
A
B

C-1
SQUARE GRID SYSTEM
(A=B)


SITE BOUNDARY
A
c
B
b
a
C

C-2
TRIANGULAR GRID SYSTEM
(A=B<a=b=c=60o)


SOURCE
CONTAMINANT MIGRATION

C-3
MODIFIED GRID SYSTEM TO
ACCOUNT FOR DIRECTIONAL CORRELATION

samples being obtained at 100-ft spacings. Following review of the preliminary data, intensive sampling may be warranted in a number of discrete locations on the site. This intensive sampling may then be performed at the previously established 10-ft grid intersections.

The distance between the grid lines will determine the number of intersections and hence the number of potential sampling points within a specified area. As the grid line spacings increase, the number of potential sampling points will decrease for any given sampling area. Confidence interval methodology can be used to select optimal grid spacing.

## C.6 QUALITY CONTROL SAMPLES

Various types of samples may be obtained during a remedial investigation in order to provide quality control information for interpretation of data including:

- Background samples
- Critical samples
- Collocated and replicate samples
- Split samples
- Field and trip blanks
- Matrix spikes

In all cases QC samples must be submitted to the laboratory as blind samples.

### C.6.1 BACKGROUND SAMPLES

Inclusion of background samples in an RI sampling task must be taken into consideration during the DQO process. A background sample is one taken from media characteristic of the site but outside the zone of contamination. Monitoring data as well as available literature on natural background concentrations of chemicals in the area should be collected, reviewed and/or verified to determine background conditions. Background data should be defined as either natural or anthropogenic chemical contamination resulting from a source or sources other than the site undergoing assessment.

### C.6.2 CRITICAL SAMPLES

Critical data points are sample locations for which valid data must be obtained in order for the sampling event to be considered complete. An example of a critical data point may be an upgradient well in a ground water contamination study or any other data point considered vital to the decision making process. Critical data points should be carefully considered in the sampling plan design. In some cases, taking critical data point samples in duplicate is appropriate. A common problem of any sample design is the loss of data during implementation of the design. Care must be taken to determine the set of points for which data must be collected in order to analyze the results accurately. The set of points which must be collected are called the "critical points." Critical points may be defined in terms of the minimum number of data points which must be collected and analyzed. Critical data points should be identified in every completeness statement developed during the DQO process.

### C.6.3 COLLOCATED AND REPLICATE SAMPLES

Collocated samples are independent samples collected in such a manner that they are equally representative of the parameter(s) of interest at a given point in space and time. Examples of collocated samples include: samples from two air quality analyzers sampling from a common sample manifold, two water samples collected at essentially the same time and from the same point in a lake, or side-by-side soil core samples.

Collocated samples, when collected, processed, and analyzed by the same organization, provide intralaboratory precision information for the entire measurement system including sample acquisition, homogeneity, handling, shipping, storage, preparation and analysis. Collocated samples, when collected, processed and analyzed by different organizations, provide interlaboratory precision information for the entire measurement system.

Replicate samples are samples that have been divided into two or more portions at some step in the measurement process. Each portion is then carried through the remaining steps in the measurement process. A sample may be replicated in the field or at different points in the analytical process. For field replicated samples, precision information would be gained on homogeneity (to a lesser extent than for collocated samples), handling, shipping, storage, preparation, and analysis. For analytical replicates, precision information would be gained on preparation and analysis. Examples of field replicated samples include a soil core sample that has been collected and poured into a common container for mixing before being split and placed in individual sample containers.

Collocated samples can be used to estimate the overall precision of a data collection activity. Sampling error can be estimated by the inclusion of collocated and replicated versions of the same sample. If a significant difference in precision between the two subsets is found, it may be attributed to sampling error. As a data base on field sampling error is accumulated, the magnitude of sampling error can be determined.

The following are suggested guidelines for the inclusion of collocated and replicated samples in field programs:

- Ground and surface water - one out of every 20 investigative samples should be collocated. Replicated samples could be substituted where appropriate. These samples should be spread out over the sampling event, preferably at least one for each day of sampling.

- Soil, sediments and solids - one out of every 20 investigative samples should be field replicated or collocated. To estimate sampling error, collocated and field replicated samples should be of the same investigative sample. These samples should be spread out over the sampling event, preferably one per each day of sampling.

### C.6.4 SPLIT SAMPLES

Split samples are replicate samples divided into two portions, sent to different laboratories, and subjected to the same environmental conditions and steps in the measurement process. They serve as an oversight function in assessing the analytical portion of the measurement system.

### C.6.5 TRIP AND FIELD BLANKS

Trip blanks generally pertain to volatile organic samples only. Trip blanks are prepared prior to the sampling event in the actual sample containers and are kept with the investigative samples throughout the sampling event. They are then packaged for shipment with the other samples and sent for analysis. There should be one trip blank included in each sample shipping container. At no time after their preparation are the sample containers opened before they reach the laboratory.

Field blanks are defined as samples which are obtained by running analyte-free deionized water through sample collection equipment (bailer, pump, auger, etc.) after decontamination, and placing it in the appropriate sample containers for analysis. These samples will be used to determine if decontamination procedures have been sufficient. Using the above definition, soil field blanks could be called rinsate samples. These should be included in a sampling program as appropriate.

The following guidelines for including blanks in sampling programs are suggested.

- Ground and surface water - Field blanks should be submitted at the rate of one field blank/matrix/per day or one for every 20 investigation samples, whichever results in fewer samples. Trip blanks should be included at a frequency of one per day of sampling or as appropriate.

- Soil sediments and solids - Rinsate samples should be submitted at the rate of one for every 20 investigative samples for each matrix being sampled or as appropriate.

Guidelines for blank, duplicate, and background samples are provided in Table C-1. These guidelines serve as a starting point from which to develop site-specific sampling plan QC sample numbers. In certain instances, it may be appropriate to utilize known reference materials when available for QC checking. The numbers and sources of reference materials which would provide meaningful comparison and checks for media obtained from hazardous waste sites are limited. Analytical chemists should be consulted regarding the appropriateness of use of reference materials as a QC check.

### C.6.6 MATRIX SPIKES

Many samples exhibit matrix effects, in which other sample components interfere with the analysis of contaminants of interest. Matrix spikes provide the best measurement of this effect. When done in the field, immediately after collection, they also provide a measurement of sampling, handling and preservation error. The field matrix spike does provide the best overall assessment of accuracy for the entire measurement system, as collocated samples do for precision assessment. However, there are some serious issues regarding the field spiking of environmental samples that must be considered. Field matrix spikes are generally not recommended because of the high level of technical expertise required for proper use and their sensitivity to environmental variables.

The major problems associated with field matrix spikes are due to the fact that all spike recovery data must be interpreted very carefully. Spike recoveries are subject to many competing factors, such as analyte stability, holding time, and the sample matrix. Because of the inherent variability associated with spike recoveries, the additional variability introduced by spiking samples in the field can increase the overall uncertainty associated with a data set rather than decrease it.

The two most important issues to address when considering field spiking as an option are the source of the spiking material and the technical capability of the person doing the spiking. Spiking materials that can be used are Standard Reference Materials (SRMs), EPA quality control ampules, or laboratory-prepared solutions made from pure compounds. SRMs are stand-alone standards prepared by NBS that can be placed in the appropriate sample containers and sent to the laboratory to be analyzed. The use of certified standards such as SRMs solves the "traceability" issue concerning the integrity of the blind standard and also does not require a skilled technician to prepare the standard. However, because the SRM is a stand-alone sample, it provides no information on the impact of the sample matrix on the measurement system. An aliquot of an SRM can be used to spike an environmental sample, but it would no longer be traceable and would require a person skilled in the appropriate analytical techniques, just as the use of quality control ampules or laboratory-prepared spikes do. The competence of the person doing the spiking is critical. The exact amount of spiking material must be recorded for future use in assessing recoveries. Errors in measurement of the spike or use of the wrong spiking material will cause serious problems in interpreting the usability of the data.

## TABLE C-1

## GUIDELINES FOR MINIMUM QA/QC SAMPLES FOR FIELD SAMPLING PROGRAMS

|  | DUPLICATES |  |  |  |  |
|---|---|---|---|---|---|
| MEDIA | COLLOCATED OR FIELD REPLICATE | FIELD BLANK | TRIP BLANK | BACKGROUND SAMPLE | INTER-LAB SPLIT SAMPLE |
| Aqueous | one in twenty | one in twenty | one per day of sampling | min. of two per sampling event-media | when required to meet objectives |
| Soil, sediment | one in twenty | one in twenty |  | min. of two per sampling event-media | when required to meet objectives |
| Air | one in twenty | not available | one per day of sampling | min. of two per sampling event-media | when required to meet objectives |
| Source material | one in twenty | not usually required |  |  | when required to meet objectives |

NOTE: This table is provided to serve as a guideline only; QA/QC sample requirements must be developed on a site-specific basis. Laboratory blanks and spikes are method specific and are not included in this table.

In summary, field matrix spikes are not recommended unless the appropriate technical support is available. Absolute attention to all details is required to obtain useful information from the procedure. If field matrix spikes are used, the results should be compared with laboratory matrix spike results.

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# APPENDIX D

# REVIEW OF QAMS CHECKLIST

# APPENDIX D

# REVIEW OF QAMS DQO CHECKLIST

In a memorandum dated April 3, 1983, Mr. Stanley Blacker, Director of the Quality Assurance Management Staff (QAMS) issued a checklist to be used by QAMS staff during their review of DQOs. The purpose of this appendix is to review the QAMS checklist with respect to this RI/FS DQO guidance.

The QAMS checklist is designed for use in reviewing specific DQOs rather than an approach to DQO development for a complex process such as an RI/FS. This appendix presents a review of the checklist items, along with a reference to the section where the item is addressed and/or a comment regarding the applicability of the item to the RI/FS DQO process.

The RI/FS process involves multiple levels of data and data uses, and culminates in a decision regarding the degree of remedial response to be implemented for a site. Decisions are based on analytical and other measurement data which are often integrated to interpret various aspects of a site's characteristics. Thus, many different sets of DQOs may be required for a given RI/FS.

# APPENDIX D

## SUMMARY OF DQO CHECKLIST ITEMS WITH RESPECT TO RI/FS DQO APPLICABILITY

| DQO CHECKLIST ITEM | COMMENT RE: RI/FS DQO APPLICABILITY |
|---|---|
| A-1. The decision maker and associated users are clearly identified. | The key RI/FS decision is remedy selection (i.e., ROD/EDD signature). For the majority of RI/FS projects, remedy selection is delegated to the Regional Administrator (RA). Program Management responsibilities are delegated to the Waste Management Division Director and Managers, with project specific management and oversight assigned to Remedial Project Managers (RPM). In this role the regional EPA RPM, is responsible for coordinating the DQO development process, and overseeing remedial contractors, state officials, or private parties conducting the RI/FS. Associated data users include primary, secondary and technical support and project review/audit personnel. |
| A-2. The decision maker and associated data users have been involved in the development of DQOs. | See Section 2.0, Stage 1 - Identify & Involve Data Users. |
| B-1a. A statement of the decision(s) that depend(s) on the results of this data collection activity. | The decision(s) that result from the RI/FS process involve multiple levels of data for multiple purposes. See Section 3.0, Stage 1 - Specify RI/FS Objectives. |
| B-1b. If the data collection activity is of an exploratory nature and not formally linked with a regulatory decision, then the document should include a clear explanation of the purpose for which the environmental data are intended. | See Section 4.0, Stage 2 Identify Data Uses/Needs. |

## APPENDIX D
(continued)

## SUMMARY OF DQO CHECKLIST ITEMS WITH RESPECT TO RI/FS DQO APPLICABILITY (continued)

| DQO CHECKLIST ITEM | COMMENT RE: RI/FS DQO APPLICABILITY |
|---|---|
| B-2. Statements of each specific question that will be addressed in the data collection activity and the type of conclusion that is anticipated as an appropriate answer to each question. The conclusions should depend only on measurement data. | See Section 4.0, Stage 2 |
| B-3. A clear statement of the way in which each conclusion of the study will be represented, in terms of the results of statistical calculations made with the data. | See Section 4.0, Stage 2 - The conclusions of an RI/FS study are highly interdependent. The format for data presentation will vary, based upon data quantity. A statistical approach may not be feasible. |
| B-4. Statements of the acceptable levels of precision and accuracy associated with each of the conclusions depend on measurement data. | See Section 4.0, Stage 2. |
| B-5. A definition of the population to which each of the conclusions apply, including definitions of all subpopulations or strata. | See Section 4.0, Stage 2. |
| B-6. Definitions of the variables that will be measured. | See Section 4.0, Stage 2. |
| B-7. The acceptable levels of precision and accuracy for the measurements to be made. | See Section 4.0, Stage 2. |
| B-8. A flow chart or spread sheet illustrating the relationship between the measurement data and each conclusion that will be made with the data. | See Section 4.0, Stage 2. |

# APPENDIX E

# POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

## (50 FR 47948)

# APPENDIX E

## POTENTIALLY APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

1. EPA's Office of Solid Waste administers, inter alia, the Resource Conservation and Recovery Act of 1976, as amended (Pub. L. 94-580, 90 Stat 95, 42 U.S.C. 6901 et seq.). Potentially applicable or relevant requirements pursuant to that Act are:

   a. Open Dump Criteria - Pursuant to RCRA Subtitle D criteria for classification of solid waste disposal facilities (40 CFR Part 257).
   Note: Only relevant to nonhazardous wastes.

   b. In most situations Superfund wastes will be handled in accordance with RCRA Subtitle C requirements governing standards for owners and operators of hazardous waste treatment, storage, and disposal facilities: 40 CFR Part 264, for permitted facilities, and 40 CFR Part 265, for interim status facilities.

- Ground Water Protection (40 CFR 264.90-264.109).
- Ground Water Monitoring (40 CFR 265.90-265.94).
- Closure and Post Closure (40 CFR 264.110-264.120, 265.110-265.112).
- Containers (40 CFR 264.170-264.178, 265.170-265.177).
- Tanks (40 CFR 264.190-264.200, 265.190-265.199).
- Surface Impoundments (40 CFR 264.220-264.249, 265.220-265.230).
- Waste Piles (40 CFR 264.250-264.269, 265.250-265.258)
- Land Treatment (40 CFR 264.270-264.299, 265.270-265.282).
- Landfills (40 CFR 264.300-264.339, 265.300-265.316).
- Incinerators (40 CFR 264.340-264.999, 265.340-265.369).
- Dioxin-containing Wastes, (50 FR 1978). Includes the final rule for the listing of dioxin containing waste.

2. EPA's Office of Water administers several potentially applicable or relevant and appropriate statutes and regulations issued thereunder:

   a. Section 14.2 of the Public Health Service Act as amended by the Safe Drinking Water Act as amended (Pub. L. 93-523, 88 Stat 1660, 42 U.S.C. 300f et sec.)

- Maximum Contaminant Levels (for all sources of drinking water exposure). (40 CFR 141.11-141.16)
- Underground Injection Control Regulations. (40 CFR Parts 144, 145, 146, and 147)

b. Clean Water Act as amended (Pub. L. 92-500, 86 Stat 816, 33 U.S.C. 1251 et. seq.)

- Requirements established pursuant to sections 301, 302, 303 (including State water quality standards), 306, 307, (including Federal Pretreatment requirements for discharge into a publicly owned treatment works), and 403 of the Clean Water Act. (40 CFR Parts 131, 400-469)

c. Marine Protection, Research, and Sanctuaries Act (33 U.S.C. 1401).

- Incineration at sea requirements. (40 CFR Part 220-225, 227, 228. See also 40 CFR 125.120-125.124)

3. EPA's Office of Pesticides and Toxic Substances

- Toxic Substances Control Act (15 U.S.C. 2601).
- PCB Requirements Generally: 40 CFR Part 761; Manufacturing Processing, Distribution in Commerce, and Use of PCBs and PCB Items (40 CFR 761.20-761.30); Markings of PCBs and PCB Items (40 CFR 761.40-761.45); Storage and Disposal (40 CFR 761.60-761.79). Records and Reports (40 CFR 761.180-761.185). See also 40 CFR 129.105, 750.
- Disposal of Waste Material Containing TCDD. (40 CFR Parts 775.180-775.197).

4. EPA's Office of External Affairs

- Section 404(b)(1) Guidelines for Specification of Disposal Sites for Dredged or Fill Material (40 CFR Part 230).
- Procedures for denial or Restriction of Disposal Sites for Dredged Material (Section 404(c) Procedures, 40 CFR Part 231).

5. EPA's Office of Air and Radiation administers several potentially applicable or relevant and appropriate statutes and regulations issued thereunder:

a. The Uranium Mill Tailings Radiation Control Act of 1978 (42 U.S.C. 2022).

- Uranium mill tailing rules - Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings
  (40 CFR Part 192).

b. Clean Air Act (42 U.S.C. 7401).

- National Ambient Air Quality Standards for total suspended particulates (40 CFR Part 50.6-50.7)
- National Ambient Air Quality Standards for ozone (40 CFR 50.9).
- Standards for Protection Against Radiation - high and low level radioative waste rule. (10 CFR Part 20). See also 10 CFR Parts 10, 40, 60, 61, 72, 960, 961.
- National Emission Standard for Hazardous Air Pollutants for Asbestos. (40 CFR 61.140-61.156). See also 40 CFR 427.110-427.116, 763. National Emission Standard for Hazardous Air Pollutants for Radionuclides (40 CFR Part 61, 10 CFR 20.101-20.108).

6. Other Federal Requirements

   a. OSHA requirements for workers engaged in response activities are codified under the Occupational Safety and Health Act of 1970 (29 U.S.C. 651). The relevant regulatory requirements are included under:

   - Occupational Safety and Health Standards (General Industry Standards) (29 CFR Part 1910).
   - The Safety and Health Standards for Federal Service Contracts (29 CFR Part 1926).
   - The Shipyard and Longshore Standards (29 CFR Parts 1915, 1918).
   - Recordkeeping, reporting, and related regulations (29 CFR Part 1904).

   b. Historic Sites, Buildings, and Antiquities Act (16 U.S.C. 461).

   c. National Historic Preservation Act, 16 U.S.C. 470. Compliance with NEPA required pursuant to 7 CFR Part 650. Protection of Archaelogical Resources: Uniform Regulations -- Department of Defense (32 CFR Part 229, 229.4), Department of the Interior (43 CFR Part 7, 7.4).

   d. D.0.T. Rules for the Transportation of Hazardous Materials, 49 CFR Parts 107, 171.1-171.500. Regulation of activities in or affecting waters of the United States pursuant to 33 CFR Parts 320-329. The following requirements are also triggered by Fund-financed actions:

   - Endangered Species Act of 1973, 16 U.S.C. 1531. (Generally, 50 CFR Parts 81, 225, 402). Wild and Scenic Rivers Act, 16 U.S.C. 1271.
   - Fish and Wildlife Coordination Act, 16 U.S.C. 661 note.
   - Fish and Wildlife Improvement Act of 1978, and Fish and Wildlife Act of 1956, 16 U.S.C. 742a note.
   - Fish and Wildlife Conservation Act of 1980, 16 U.S.C. 2901. (Generally, 50 CFR Part 83).
   - Coastal Zone Management Act of 1972, 16 U.S.C. 1451. (Generally, 15 CFR Part 930 and 15 CFR 923.45 for Air and Water Pollution Control Requirements).

## OTHER FEDERAL CRITERIA, ADVISORIES, GUIDANCES, AND STATE STANDARDS TO BE CONSIDERED

1. Federal Criteria, Advisories and Procedures

   - Health Effects Assessments (HEAs).
   - Recommended Maximum Concentration Limits (RMCLs).
   - Federal Water Quality Criteria (1976, 1980, 1984). Note: Federal Water Quality Criteria are not legally enforceable. State water quality standards are legally enforceable, and are developed using appropriate aspects of Federal Water Quality Criteria. In many cases, State

water quality standards do not include specific numerical limitations on a large number of priority pollutants. When neither State standards nor MCLs exist for a given pollutant, Federal Water Quality Criteria are pertinent and therefore are to be considered.

- Pesticide registrations.
- Pesticide and food additive tolerances and action levels. Note: Germane portions of tolerances and action levels may be pertinent and therefore are to be considered in certain situations.
- Waste load allocation procedures, EPA Office of Water.
- Federal sole source aquifer requirements.
- Public health basis for the decision to list pollutants as hazardous under section 112 of the Clean Air Act.
- EPA's Ground-water Protection Strategy.
- New Source Performance Standards for Storage Vessels for Petroleum Liquids.
- TSCA health data.
- Pesticide registration data.
- TSCA chemical advisories (2 or 3 issued to date).
- Advisories issued by FWS and NWFS under the Fish and Wildlife Coordination Act.
- Executive Orders related to Floodplains (11988) and Wetlands (11990) as implemented by EPA's August 6, 1985, Policy on Floodplains and Wetlands Assessments for CERCLA Actions.
- TSCA Compliance Program Policy.
- OSHA health and safety standards that may be used to protect public health (non-workplace).
- Health Advisories, EPA Office of Water

2. State Standards

- State Requirements on Disposal and Transport of Radioactive wastes.
- State Approval of Water Supply System Additions or Developments.
- State Ground Water Withdrawal Approvals. Requirements of authorized (Subtitle C of RCRA) State hazardous waste programs.
- State Implementation Plans and Delegated Programs Under Clean Air Act.
- All other State requirements, not delegated through EPA authority.
- Approved State NPDES programs under the Clean Water Act.

- o Approved State UIC programs under the Safe Drinking Water Act.

  Note: Many other State and local requirements could be pertinent. Forthcoming guidance will include a more comprehensive list.

3. USEPA RCRA Guidance Documents

   - o Draft Alternate Concentration Limits (ACL) Guidance

A. EPA's RCRA Design Guidelines

   1. Surface Impoundments, Liners Systems, Final Cover and Freeboard Control.
   2. Waste Pile Design - Liner Systems.
   3. Land Treatment Units.
   4. Landfill Design - Liner Systems and Final Cover.

B. Permitting Guidance Manuals

   1. Permit Applicant's Guidance Manual for Hazardous Waste Land Treatment, Storage, Disposal Facilities.
   2. Permit Writer's Guidance Manual for Hazardous Waste Land Treatment, Storage, and Disposal Facilities.
   3. Permit Writer's Guidance Manual for Subpart F.
   4. Permit Applicants Guidance Manual for the General Facility Standards.
   5. Waste Analysis Plan Guidance Manual.
   6. Permit Writer's Guidance Manual for Hazardous Waste Tanks.
   7. Model Permit Application for Existing Incinerators.
   8. Guidance Manual for Evaluating Permit Applications for the Operation of Hazardous Waste Incinerator Units.
   9. A guide for Preparing RCRA Permit Applications for Existing Storage Facilities.
   10. Guidance Manual on Closure and Post-Closure Interim Status Standards.

C. Technical Resource Documents (TRDs)

   1) Evaluating Cover Systems for Solid and Hazardous Waste.
   2) Hydrologic Simulation of Solid Waste Disposal Sites.
   3) Landfill and Surface Impoundment Performance Evaluation.
   4) Lining of Water Impoundment and Disposal Facilities.

5) Management of Hazardous Waste Leachate.

6) Guide to the Disposal of Chemically Stabilized and Solidified Waste.

7) Closure of Hazardous Waste Surface Impoundments.

8) Hazardous Waste Land Treatment.

9) Soil Properties, Classification, and Hydraulic Conductivity Testing.

D. Test Methods for Evaluating Solid Waste

1) Solid Waste Leaching Procedure Manual.

2) Methods for the Prediction of Leachate Plume Migration and Mixing.

3) Hydrologic Evaluation of Landfill Performance (HELP) Model Hydrologic Simulation on Solid Waste Disposal Sites.

4) Procedures for Modeling Flow Through Clay Liners to Determine Required Liner Thickness.

5) Test Methods for Evaluating Solid Wastes.

6) A Method for Determining the Compatibility of Hazardous Wastes.

7) Guidance Manual on Hazardous Waste Compatibility.

4. USEPA Office of Water Guidance Documents

A. Pretreatment Guidance Documents

1) 304(g) Guidance Document Revised Pretreatment Guidelines (3) Volumes

B. Water Quality Guidance Documents

1) Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters (1977)

2) Technical Support Manual: Waterbody Surveys and Assessments for Conducting Use Attainability Analyses (1983)

3) Water-Related Environmental Fate of 129 Priority Pollutants (1979)

4) Water Quality Standards Handbook (1983)

5) Technical Support Document for Water Quality-based Toxics Control.

C. NPDES Guidance Documents

1) NPDES Best Management Practices Guidance Manual (June 1981)

2) Case studies on toxicity reduction evaluation (May 1983).

D. Ground Water/UIC Guidance Document

1) Designation of a USDW

2) Elements of Aquifer Identification

3) Interim guidance for public participation

4) Definition of major facilities

5) Corrective action requirements

6) Requirements applicable to wells injecting into, through or above an aquifer which has been exempted pursuant to Section 146.104(b)(4).

7) Guidance for UIC implementation on Indian lands.

5. USEPA Manuals from the Office of Research and Development

1) EW 846 methods - laboratory analytic methods.

2) Lab protocols developed pursuant to Clean Water Act Section 304(h).

## APPENDIX F

## HISTORICAL PRECISION AND ACCURACY DATA CLASSIFIED BY MEDIA BY ANALYTICAL LEVEL

## APPENDIX F CONTENTS

## HISTORICAL PRECISION AND ACCURACY TABLES

Introduction

Water: Level III
Water: Level IV

Soil: Level I
Soil: Level II
Soil: Level III
Soil: Level IV

Air: Level I
Air: Level II
Air: Level III

Other Media: Level III

# INTRODUCTION

The data in this Appendix have been compiled to assist the reader in selecting an analytical method appropriate for each data use. The methods are classified by media and by analtyical levels defined as follows:

- Level I - field screening or analysis using portable instruments. Results are often not compound specific and not quantitative but results are available in real-time.
- Level II - field analysis using more sophisticated portable analytical instruments; in some cases, the instruments may be set up in a mobile or onsite laboratory. There is a wide range in the quality of data that can be generated. Quality depends on the use of suitable calibration standards, reference materials, and sample preparation equipment; and the training of the operator. Results are available in real-time or several hours.
- Level III - all analyses performed in an offsite analytical laboratory using standard, documented procedures. The laboratory may or may not be a CLP laboratory.
- Level IV - CLP routine analytical services (RAS). All analyses are performed in an offsite CLP analytical laboratory following CLP protocols.

Precision and accuracy data are presented in tabular fashion. Footnotes to each table cite the sources of the data and the concentration or concentration range at which the precision and accuracy were determined. When no concentration is cited no concentration information was available in the source material.

Precision is a measure of the variability in repeated measurements of the same sample compared to the average value. Precision is reported as % Relative Standard Deviation (RSD). The lower the % RSD, the more precise the data.

RSD is calculated for a pair of replicates using the following formula:

$$\%RSD = [2|X_1 - X_2|/(X_1 + X_2)]\,(100/\sqrt{2})$$

where $X_1$ is measurement #1 of a replicate

$X_2$ is measurement #2 of a replicate

Accuracy is reported as % Bias; as % Bias approaches zero, accuracy increases. Bias is calculated by the following formula:

$$\%\ Bias = \frac{X-Y}{Y}\,(100)$$

where Y is the known concentration or true value
X is the reported concentration

Bias measures the systematic error within an analytical technique.

## HISTORICAL PRECISION AND ACCURACY DATA/WATER [a]

### LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

| ANALYTES | METHOD (TECHNIQUE) | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % BIAS |
|---|---|---|---|---|
| **BENZENE** | 624 (GC/MS) | 11 ug/l | 16 | 0 |
| | | 480 ug/l | 21 | -16 |
| | 8240 (GC/MS) | 5-100 ug/l | 21 | 12 |
| **BROMODICHLOROMETHANE** | 624 (GC/MS) | 8 ug/l | 28 | -8.8 |
| | | 480 ug/l | 18 | -6.7 |
| | 501.1 (PURGE & TRAP GC/MS) | 0.9 ug/l | 66 | 0 |
| | | 550 ug/l | 34 | -3.8 |
| | 501.2 (EXTRACTION GC/MS) | 1.8 ug/l | 61 | 33 |
| | | 170 ug/l | 23 | -19 |
| **BROMOFORM** | 624 (GC/MS) | 9 ug/l | 32 | -23 |
| | | 400 ug/l | 30 | 10 |
| | 501.1 (PURGE & TRAP GC/MS) | 4.8 ug/l | 44 | -27 |
| | | 550 ug/l | 41 | 7.5 |
| | 501.2 (EXTRACTION GC/MS) | 6 ug/l | 14 | -23 |
| | | 170 ug/l | 15 | 1.8 |

## HISTORICAL PRECISION AND ACCURACY DATA/WATER [a]
(continued)

### LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

| ANALYTES | METHOD (TECHNIQUE) | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % BIAS |
|---|---|---|---|---|
| CHLOROFORM | 624<br>(GC/MS) | 4.5 ug/l | 31 | 2.2 |
| | | 300 ug/l | 14 | -0.6 |
| | 501.1<br>(PURGE & TRAP GC/MS) | 0.9 ug/l | 64 | 44 |
| | | 550 ug/l | 14 | -0.02 |
| | 501.2<br>(EXTRACTION GC/MS) | 1.8 ug/l | 68 | -39 |
| | | 170 ug/l | 26 | -1.2 |
| DIBROMOCHLOROMETHANE | 624<br>(GC/MS) | 8.1 ug/l | 13 | -3.1 |
| | | 360 ug/l | 19 | 10 |
| | 501.1<br>(PURGE & TRAP GC/MS) | 0.8 ug/l | 35 | -12.5 |
| | | 550 ug/l | 36 | 4.7 |
| | 501.2<br>(EXTRACTION GC/MS) | 1.8 ug/l | 37 | 0 |
| | | 170 ug/l | 13 | 0.02 |
| DIOXIN | 613<br>(GC/MS) | 21 ng/l | 25 | N.A. |
| | | 202 ng/l | 21 | N.A. |

## HISTORICAL PRECISION AND ACCURACY DATA/WATER [a]
(continued)

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

| ANALYTES | METHOD (TECHNIQUE) | CONCENTRATION RANGE | PRECISION % RSD | ACCURANCY % BIAS |
|---|---|---|---|---|
| METHYLENE CHLORIDE | 624 | 7.2 ug/l | 78 | -17 |
| | (GC/MS) | 480 ug/l | 52 | -25 |
| TOLUENE | 624 | 13.5 ug/l | 19 | 15 |
| | (GC/MS) | 600 ug/l | 31 | -14 |
| | 8240 | 25 ug/l | 19 | -10 |
| | (GC/MS) | 75 ug/l | | |
| TRICHLOROETHENE | 624 | 5.4 ug/l | 48 | 44 |
| | (GC/MS) | 360 ug/l | 39 | -2.3 |
| | 8240 | 25 ug/l | 24 | 5 |
| | (GC/MS) | 75 ug/l | | |
| LEAD | 200.7 | 42 ug/l | 34 | 31 |
| | (ICP) | 47.7 ug/l | 5 | 4.4 |
| | 239.1 | 12 ug/l | 5.9 | 17 |
| | (FLAME AA) | 105 ug/l | 6.7 | -1.9 |
| | 239.2 | 10 ug/l | 53 | -22 |
| | (FURNACE AA) | 234 ug/l | 19 | -3.1 |

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a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

## HISTORICAL PRECISION AND ACCURACY DATA/WATER
(Continued)

## LEVEL III ANALYTICAL TECHNIQUES - SW-846 METHODS

| Method Number | Method Name | Data Source | Range of Recovery (%) | Precision (%) | MDL (mg/l) |
|---|---|---|---|---|---|
| ORGANICS: | | | | | |
| 8010 | Halogenated Volatile Organics | SW 846 | 75.1 - 106.1 | 2.0 - 25.1 | 0.03 - 0.52 |
| 8020 | Aromatic Volatile Oranics | SW 846 | 77.0 - 120 | 9.4 - 27.7 | 0.2 - 0.4 |
| 8030 | Acrolein, Acrylonitrile, Acetonitrile | SW 846 | 96 - 107 | 5.6 - 11.6 | 0.5 - 0.6 |
| 8040 | Phenols | SW 846 | 41 - 86 | 7.9 - 16.5 | 058 - 2.2 |
| 8060 | Esters | EPA 606 | 82 - 94 | 1.3 - 6.5 | 0.29 - 3.0 |
| 8080 | Organochlorine Pesticides and PCBs | SW 846 | 86 - 97 | 1.3 - 6.5 | 0.29 - 3.0 |
| 8090 | Nitroaromatics and Cyclic Ketones | SW 846 | 63 - 71 | 3.1 - 5.9 | 0.06/ND |
| 8100 | Polynuclear Aromatic Hydrocarbons | | NA[b] | NA | NA |
| 8120 | Chlorinated Hydrocarbons | SW 846 | 76 - 99 | 10 - 25 | 0.03 - 1.34 |
| 8140 | Organophosphorous Pesticides | SW 846 | 56.5 - 120.7 | 5.3 - 19.9 | 0.1 - 5.0 |
| 8150 | Chlorinated Herbicides | SW 846 | NA | NA | 0.1 - 200 |
| 8240 | Volatile Organics | SW 846 | 95 - 107 | 9 - 28 | 1.6 - 6.9 |
| 8250 | GC/MS Semivolatiles (Packed Column) | | 41 - 143 | 20 -145 | 0.9 - 44 |
| 8040 | GC/MS Semivolatiles (Capillary) | | NA | NA | NA |

## HISTORICAL PRECISION AND ACCURACY DATA/WATER
(Continued)

## LEVEL III ANALYTICAL TECHNIQUES - SW-846 METHODS

| Method Number | Method Name | Data Source | Range of Recovery (%) | Precision (%) | MDL (mg/1) |
|---|---|---|---|---|---|
| 8310 | Polynuclear Aromalic Hydrocarbons (HPLC) (Capillary) | SW 846 | 78 - 116 | 7.3 - 12.9 | 0.03 - 2.3 |
| INORGANICS: | Metals (ICAP) | EPA 200.7 | NA | 3 - 21.9 (RSD) | 1.3 - 75 Mg/1 |
| | Metals (FLAME) 7000 Series | EPA 200 | NA | NA | 0.01 - 5 |
| 7000 Series | Metals (FLAME LESS/GF) | EPA 200 | NA | NA | 0.001 - 0.2 Mg/1 |
| 7470 | Metals (MERCURY) | EPA 245.2 | 87 - 125 | 0.9 - 4.0 | 0.0002 |
| 9010 | Cyanides | EPA 335.2 | 85 - 102 | 0.2 - 15.2 | 0.02 Mg/1 |
| 9030 | Sulfides | EPA 376.1 | NA | NA | 1 Mg/1 |

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a. For water only

b. NA Not Available

NOTES: Method Detection Limit (MDL) as listed on this table is the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.

Accuracy, presented as an average percent recovery, was determined from replicate (10-25) analyses of water and wastewater samples fortified with known concentrations of the analyte of interest at or near the detection limit. In most cases this was less than 10 times the MDL.

Precision data are used to measure the variability of these repetitive analyses reported as a single standard deviation or, as a percentage of the recovery measurements. For presentation purposes accuracy, precision and MDL information is presented as an average range of individual values for every analyte covered by the procedure. If specific information on a particular compound is required, the specific analytical method cited should be consulted.

## HISTORICAL PRECISION AND ACCURACY DATA/WATER[a]

## LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

| ANALYTES | TECHNIQUE | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % Bias |
|---|---|---|---|---|
| Volatiles[b] | Purge & Trap GC/MS | N.A.[c] | | |
| Methylene chloride | | | 56 | +36.6 |
| 1,1-Dichloroethene | | | 20 | -26.3 |
| 1,1-Dichloroethane | | | 13 | -46.4 |
| Trans-1,2-Dichloroethene | | | 31 | -21.7 |
| Chloroform | | | 12 | -21.1 |
| 1,2-Dichloroethane | | | 13 | +2.4 |
| 1,1,1-Trichloroethane | | | 19 | -41.0 |
| Carbon Tetrachloride | | | 12 | -32.1 |
| 1,1,2,2-Tetrachloroethane | | | 11 | -5.8 |
| Bromodichloromethane | | | 19 | -13.0 |
| 1,2-Dichloropropane | | | 18 | -12.9 |
| Trans-1,3-Dichloropropene | | | 31 | -41.2 |
| Trichloroethene | | | 17 | -22.8 |
| Dibromochloromethane | | | 14 | -3.3 |
| 1,1,2-Trichloroethane | | | 11 | -7.0 |
| Benzene | | | 12 | -3.3 |
| Cis-1,3-Dichloropropene | | | 22 | -35.5 |
| Bromoform | | | 16 | +6.5 |
| Tetrachloroethene | | | 13 | -42.5 |
| Toluene | | | 14 | -23.3 |
| Chlorobenzene | | | 14 | -15.9 |
| Ethyl Benzene | | | 4 | -31.9 |
| Semivolatiles[d] | GC/MS | N.A.[c] | | |
| bis(2-Chloroethyl)ether | | | 24 | -16 |
| 2-Chlorophenol | | | 29 | -21 |
| 1,3-Dichlorobenzene | | | 24 | -48 |
| 1,4-Dichlorobenzene | | | 21 | -25 |
| 1,2-Dichlorobenzene | | | 29 | -28 |
| 2-Methylphenol | | | 29 | -30 |
| bis(2-Chloroisopropyl)ether | | | 25 | -22 |

# HISTORICAL PRECISION AND ACCURACY DATA/WATER

## LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

| ANALYTES | TECHNIQUE | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % Bias |
|---|---|---|---|---|
| Semivolatiles[d] | GC/MS | N.A.[c] | | |
| 4-Methylphenol | | | 33 | -36 |
| N-Nitroso-di-n-propylamine | | | 31 | +0.3 |
| Nitrobenzene | | | 32 | -23 |
| Isophorone | | | 23 | -8 |
| 2-Nitrophenol | | | 30 | -21 |
| bis(2-Chloroethoxy)methane | | | 34 | -2.6 |
| 2,4-Dichlorophenol | | | 29 | -20 |
| 1,2,4-Trichlorobenzene | | | 30 | -47 |
| Naphthalene | | | 44 | -38 |
| 4-Chloro-3-methylphenol | | | 26 | -32 |
| 2,4,6-Trichlorophenol | | | 25 | -17 |
| 2-Chloronapthalene | | | 24 | +3.4 |
| Acenapthene | | | 28 | -12 |
| 2,4-Dinitrophenol | | | 24 | -23 |
| 2,4-Dinitrotoluene | | | 34 | -33 |
| 2,6-Dinitrotoluene | | | 25 | -48 |
| 4-Chlorophenyl-phenylether | | | 34 | +12 |
| Fluorene | | | 25 | -24 |
| 4,6-Dinitro-2-methylphenol | | | 30 | -13 |
| 4-Bromophenyl-phenylether | | | 32 | -0.1 |
| Hexachlorobenzene | | | 36 | -42 |
| Pentachlorophenol | | | 31 | -24 |
| Phenanthrene | | | 21 | -28 |
| Fluoranthene | | | 42 | -15 |
| Benzo(b)fluoranthene | | | 39 | -10 |
| Benzo(a)pyrene | | | 42 | -29 |

## HISTORICAL PRECISION AND ACCURACY DATA/WATER
(continued)

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

| ANALYTES | TECHNIQUE | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % Bias |
|---|---|---|---|---|
| Metals[e] | | | | |
| Aluminum | ICP | 1000-3000 ug/l | 9.1 | -4.3 |
| Antimony | ICP | 180-600 ug/l | 11 | -9.2 |
| Arsenic | Furnace AA | 50-150 | 9.4 | -8.3 |
| Barium | ICP | 800-1500 | 6.8 | -3.9 |
| Beryllium | ICP | 30-45 | 15 | +3.7 |
| Cadmium | ICP | 25-50 | 12 | -3.3 |
| Calcium | ICP | 1000-30000 | 6.0 | -1.6 |
| Chromium | ICP | 50-150 | 9.8 | -2.6 |
| Cobalt | ICP | 200-1000 | 6.7 | -2.9 |
| Copper | ICP | 125-250 | 6.7 | -1.1 |
| Iron | ICP | 200-800 | 10.4 | +6.5 |
| Lead | Furnace AA | 30 | 32 | -0.7 |
| Magnesium | ICP | 10000-40000 | 6.6 | -2.5 |
| Manganese | ICP | 30-150 | 6.2 | -1.0 |
| Mercury | Cold Vapor | 5-20 | 18.8 | -14.4 |
| Nickel | ICP | 160 | 9.0 | -2.5 |
| Potassium | ICP | 10000-20000 | 16.2 | -12.1 |
| Selenium | Furnace AA | 50 | 8.7 | -5.7 |
| Sodium | ICP | 10000-45000 | 8.7 | -2.8 |
| Thallium | Furnace AA | 80-100 | 17.7 | -4.2 |
| Tin | ICP | 160 | N.A.[c] | -2.5 |
| Vanadium | ICP | 60-200 | 7.6 | -0.46 |
| Zinc | ICP | 50-800 | 9.1 | +3.0 |

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a. Source: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing, Fifth Volume, ASTM STP 925, C.L. Perket, Ed., American Society for Testing Materials, Philadelphia, 1986.

b. Volatile precision and accuracy data from 26-34 laboratories' results on quarterly blind performance evaluation samples; 29-152 data points for each compound.

c. N.A. = Not Available.

d. Semivolatile precision and accuracy data from 1985 preaward program data; 22-227 data points for each compound.

e. Metals precision and accuracy data is based on performance evaluation sample results from 18 laboratories; number of data points is not given.

## HISTORICAL PRECISION AND ACCURACY DATA/SOILS

### LEVEL I FIELD SCREENING TECHNIQUES

| MEASUREMENT | INSTRUMENT (TECHNIQUE) | INSTRUMENT RANGE | INSTRUMENT PRECISION [b] | INSTRUMENT ACCURACY [c] |
|---|---|---|---|---|
| RESISTIVITY | Bison 2390 T/R (Resistivity meter) | 0-1999 millivolts | at 1% range setting, 0-5% of full scale | 2% of measured value |
| TERRAIN CONDUCTANCE | EM 31 (conductivity) | 0-1000 millimhos/meter | 2% of full scale | 5% at 20 millimhos/meter |
| TERRAIN CONDUCTANCE | EM 34-3 (conductivity) | 0-300 millimhos/meter | 2% of full scale | 5% at 20 millimhos/meter |
| Magnetic Field Intensity | EDA - Omni IV (Magnetometer) | 18000-110000 gammas | 0.02 gamma | 1 gamma at 50000 gammas at 23oC |
| Subsurface Lithology Changes | SIR-8 (Ground Penetrating Radar) | 1-81 dielectric constant | N/A[d] | N/A[d] |
| Subsurface Lithology Changes | EG+G 1225 (Seismograph) | 0-2000 milliseconds | N/A[d] | 0.01% |

## HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]
(continued)

LEVEL I FIELD SCREENING TECHNIQUES

| MEASUREMENT | INSTRUMENT (TECHNIQUE) | FIELD SCREENING RESULTS in ppm (X) | CLP RESULTS in ppm (Y) | ACCURACY[e] (% Bias) |
|---|---|---|---|---|
| TOTAL VOLATILE ORGANICS | PHOTO VAC (GC/Photoionization) | 11.4 | 26.9 | -57.6 |
| | | 22.0 | 32.8 | -32.9 |
| | | 56.0 | 129.7 | -56.8 |
| | | 139 | 228.0 & 258.0 | -42.8 |
| | | 70.0 | 126.7 | -44.8 |
| | | 24.9 | 2823.0 | +99.1 |
| | | 60.0 | 53.3 | +12.6 |
| | | 6.6 | 0.056 | +116.9 |
| | | 12.1 | 0.032 | +377.1 |
| | | 8.7 | 0.024 | +361.5 |

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a. Source: Manufacturers' manuals unless otherwise cited. Mention of specific models does not constitute and endorsement of these instrument.

b. Precision refers to reproducibility of meter or instrument reading as cited in instrument specifications.

c. Accuracy refers to instrument specifications unless otherwise cited.

d. N.A. = not available.

e. Accuracy of PhotoVac field screening results calculated by assuming that CLP results on the same samples were completely accurate. % Bias = 100 $(\frac{X-Y}{Y})$. Source of these data is CDM project files.

# HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]

LEVEL II FIELD TECHNIQUES

| ANALYTES | INSTRUMENT (TECHNIQUE) | FIELD RESULTS IN ppm (x) | CLP RESULTS IN ppm (y) | ACCURACY[b] % BIAS |
|---|---|---|---|---|
| PCBs | HNu 301 (GC/ELECTRON CAPTURE) | 6.0 | 22.0 | -72.7 |
| | | 6.0 | 6.1 | -1.6 |
| | | 6.0 | 510.0 | -98.8 |
| | | 9.0 | 3.9 | +56.7 |
| | | 13.0 | 3.0 | +333.3 |
| | | 14.0 | 3.1 | +351.6 |
| | | 14.0 | 23.5 | -40.4 |
| | | 21.0 | 8.1 | +159.3 |
| | | 35.0 | 7.7 | 354.5 |
| | | 41.0 | 2.1 | +1,852 |
| | | 48.0 | 11.0 | +336.3 |
| | | 50.0 | 460.0 | -89.1 |
| | | 65.0 | 23.1 | +181.4 |
| | | 67.0 | 18.7 | +258.3 |
| | | 92.0 | 75.0 | 22.7 |
| | | 95.0 | 30.0 | +216.7 |
| | | 11 | 12.3 | -10.6 |
| | | 202 | 99.0 | +104.0 |
| | | 269 | 370.0 | -27.3 |
| | | 286 | 80.5 | +255.3 |
| | | 1215 | 640.0 | +90.0 |
| | | 1647 | 1040.0 | +58.4 |
| | | 3054 | 9,300 | -67.2. |

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a. Source: CDM Project files.

b. Source: Accuracy calculated by assuming that CLP results on the same samples were completely accurate. % Bias = 100 $\frac{(x-y)}{y}$

## HISTORICAL PRECISION AND ACCURACY DATA/SOIL[a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

| ANALYTE | METHOD (TECHNIQUE) | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % BIAS |
|---|---|---|---|---|
| DIOXINS | 8280 | 5 ppb | 6-30 | N.A. |
| | (HPLC/LRMS) | 125 ppb | 3-10 | N.A. |
| | JAR EXTRACTION GC/MS | 1 ppb | 20 | 0 |
| | | 10 ppb | 10 | -18 |

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a. Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

## HISTORICAL PRECISION AND ACCURACY DATA/SOILS[a]

## LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

| ANALYTES | TECHNIQUE | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % Bias |
|---|---|---|---|---|
| Volatiles[b] | Purge & Trap GC/MS | N.A.[c] | | |
| Chloroform | | | 8.0 | -0.1 |
| 1,2-Dichloroethane | | | 13.1 | +11.1 |
| Dibromochloromethane | | | 35.0 | -12.0 |
| Benzene | | | 32.1 | -10.3 |
| Bromoform | | | 16.6 | -12.1 |
| 2-Hexanone | | | 16.6 | -45.5 |
| Toluene | | | 13.8 | +13.7 |
| Chlorobenzene | | | 21.2 | +13.2 |
| Semivolatiles[d] | GC/MS | N.A.[c] | | |
| 1,4-Dichlorobenzene | | | 27 | -51 |
| Nitrobenzene | | | 21 | -48 |
| Isophorone | | | 24 | -47 |
| 2-Nitrophenol | | | 35 | -36 |
| 2,4-Dichlorophenol | | | 31 | -59 |
| 1,2,4-Trichlorobenzene | | | 28 | -43 |
| Penta Chlorophenol | | | 17 | -48 |
| Pyrene | | | 25 | -15 |
| 2-Methylnaphthalene | | | 26 | -42 |
| bis-(2-Ethylhexyl)phthalate | | | 33 | -2 |
| Phenol | | | 38 | -27 |
| Acenaphthylene | | | 26 | -27 |
| Diethyphthalate | | | 16 | -20 |
| Dioxin[e] | | | | |
| 2,3,7,8-TCCD | | 1-10 ug/kg | 15 | -11.5 |

## HISTORICAL PRECISION AND ACCURACY DATA/SOILS[a]
(continued)

LEVEL IV ANALYTICAL TECHNIQUES - CLP RAS METHODS

| ANALYTES | TECHNIQUE | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % Bias |
|---|---|---|---|---|
| Metals[b] | | | | |
| Aluminum | ICP | 2-22600 ug/kg | 14.4 | -78.8 |
| Cadmium | ICP | 5.5-20 | 33.3 | +2.9 |
| Calcium | ICP | 2664-29000 | N.A.[c] | -4.2 |
| Chromium | ICP | 8.5-29600 | 7.8 | -6.1 |
| Copper | ICP | 33-109 | 11.2 | -2.5 |
| Iron | ICP | 5028-113000 | 10.7 | -27.0 |
| Lead | Furnace AA | 11.5-714 | 9.2 | -2.2 |
| Magnesium | ICP | 2428-7799 | 7.5 | -10.6 |
| Manganese | ICP | 73.5-785 | 9.4 | -15.1 |
| Mercury | Cold Vapor | 1.1-26.5 | 25.0 | -9.1 |
| Nickel | ICP | 44-67 | 15.0 | -17.0 |
| Tin | ICP | N.A.[c] | 44.1 | N.A.[c] |
| Zinc | ICP | 19-1720 | 5.8 | -6.2 |

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a. Source: Quality Control in Remedial Site Investigation: Hazardous and Industrial Solid Waste Testing, Fifth Volume, ASTM STP 925, C.L. Perket, Ed., American Society for Testing Materials, Philadelphia, 1986.

b. Volatiles precision and accuracy data is based on 1985 preaward analysis results from laboratories awarded contracts; 6-14 data points for each compound.

c. N.A. = Not Available.

d. Semivolatiles precision and accuracy data is based on 1985 preaward analysis results; 9-20 data points for each compound.

e. Dioxin precision and accuracy data is based on results of four performance evaluation samples including 120 data points.

f. Metals precision and accuracy data is based on performance evaluation sample results from 18 laboratories; number of data points is not given.

## HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

### LEVEL I FIELD SCREENING TECHNIQUES[b]

| ANALYTES | INSTRUMENT (TECHNIQUE) | INSTRUMENT RANGE | INSTRUMENT SENSITIVITY[c] | INSTRUMENT PRECISION[c] |
|---|---|---|---|---|
| Organics | Century OVA-128 (Flame Ionization) | 0.1 - 1000 ppm Methane | 0.1 ppm Methane | N.A.[d] |
| Organics | HNu PI-101 (Photoionization) | 0.1 - 2000 ppm Benzene | 0.1 ppm Benzene | ± 1% of full scale deflection |
| Organics | AID - 710 (Flame Ionization) | 0.1 - 2000 ppm Methane | 0.1 ppm Methane | N.A.[d] |
| Organics | PhotoVac (GC-Photoionization) | N.A. | 0.001 ppm Benzene | N.A.[d] |

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a. Source: Manufacturers' manuals unless otherwise cited. Mention of specific models does not constitute an endorsement of these instruments.

b. It is difficult to differentiate between Level I and Level II techniques and instrumentation. Several instruments may be used at both levels.

c. Sensitivity and precision refer to instrument specifications.

d. N.A. = Not Available.

## HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

### LEVEL II FIELD TECHNIQUES[b]

| ANALYTES | INSTRUMENT (TECHNIQUE) | INSTRUMENT RANGE | INSTRUMENT SENSITIVITY[c] | INSTRUMENT PRECISION[c] |
|---|---|---|---|---|
| Organics Compound-Specific | Miran IB (Infrared) | Compound Dependent, 0-2000 ppm | N.A.[d] | N.A.[d] |
| Organics, Compound-Specific | Century OVA-128 (GC/Flame Ionization) | 1-1000 ppm Methane | N.A. | N.A. |
| Organics, Compound-Specific | PhotoVac (GC-Photo-ionization) | N.A. | 0.001 ppm Benzene | N.A. |
| Organics, Compound-Specific | SCENTOR (Argon Ionization or Electron Capture) | N.A. | 0.001 ppm Benzene | N.A. |
| Mercury | Gold film Mercury Analyzer | N.A. | less than 0.01 ppm | N.A. |

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a. Source: Manufacturers' manuals. Mention of specific models does not constitute an endorsement of these instruments.

b. It is difficult to differentiate between Level I and Level II techniques and instrumentation. Several instruments may be used at both levels.

c. Sensitivity and precision refer to instrument specifications.

d. N.A. = Not Available.

# HISTORICAL PRECISION AND ACCURACY DATA/AIR[a]

LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS

| ANALYTES | METHOD (TECHNIQUE) | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % BIAS |
|---|---|---|---|---|
| BENZENE | CRYOGENIC TRAP/GC | 3.9 ppb | 4.0 | N.A. |
| | | 93 ppb | 5.1 | N.A. |
| | TENAX GC/MS | 7.8 ug/m3 | 11 | N.A. |
| | | 4.5 ug/m3 | 21 | N.A. |
| TOLUENE | | 10.8 ppb | 5.11 | N.A. |
| TRICHLOROETHENE | | 3.5 ppb | 4.1 | N.A. |
| | | 84 ppb | 3.7 | N.A. |
| VINYL CHLORIDE | | 7.8 ppb | 6.37 | N.A. |
| LEAD | 40 CFR 50, APP G | 0.6 ug/m3 | 8.6 | 0 |
| | (FLAME AA) | 8.01 ug/m3 | 3.9 | -3.6 |

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[a] Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

## HISTORICAL PRECISION AND ACCURACY DATA/OTHER MEDIA[a]

**LEVEL III ANALYTICAL TECHNIQUES - METHODS OTHER THAN CLP RAS METHODS**

| ANALYTE | METHOD (TECHNIQUE) | MEDIUM | CONCENTRATION RANGE | PRECISION % RSD | ACCURACY % BIAS |
|---|---|---|---|---|---|
| **LEAD** | 6010<br>(ICP) | OIL WASTE | 1.0 mg/kg | 3.1 | -10 |
| | | | -2.5 mg/kg | 22 | -20 |
| | | SOLID WASTE | 50 mg/kg | 10 | 3.4 |
| | | | 75 mg/kg | 3.7 | -0.8 |
| | SOLID | SLUDGE | 5 mg/kg | 2 | 0 |
| | | | 20 mg/kg | 11 | 55 |

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[a] Source: Draft Compendium of Information and Performance Data on Routinely Used Measurement Methods (RUMM) - Pilot Phase, RTI/3087/03, prepared for EPA Quality Assurance Management Staff, January 1986. This document should be consulted for more information on individual analytes.

# APPENDIX G

# RCRA APPENDIX VIII
CLP HSL COMPARISON

## ORGANIC COMPOUNDS ON CLP/HSL BUT NOT INCLUDED ON MODIFIED APPENDIX VIII

| Common Name | CAS RN |
|---|---|
| Acetone | 67.64.1 |
| Vinyl Acetate | 108.05.4 |
| 2-Hexanone | 591.78.6 |
| Ethylbenzene | 100.41.4 |
| Styrene | 100.42.5 |
| Xylenes (Total) | 1330-20-7 |
| Benzyl Alcohol | 100.51.6 |
| Isophorone | 78.59.1 |
| 2-Nitrophenol | 88.75.5 |
| Benzoic Acid | 65.85.0 |
| 2-Methylnaphthalene | 91.57.6 |
| 2-Nitroaniline | 88.74.4 |
| 3-Nitroaniline | 99.09.2 |
| Dibenzofuran | 132.64.9 |
| 4,Chlorophenyl-phenylether | 7005.72.3 |
| Endrin Ketone | 53494.70.5 |
| Endosulfan Sulfate | 1031.07.8 |

## ORGANIC COMPOUNDS ON MODIFIED APPENDIX VIII LIST BUT NOT INCLUDED ON CLP/HSL

| Common Name | CAS RN | Class[a] |
|---|---|---|
| Acetonitrile | 75.05.8 | CLP/VOA |
| Acetophenone | 98.86.2 | CLP/BNA |
| 2-Acetylaminofluorine | 53.96.3 | CLP/BNA |
| Acrolein | 107.02.8 | CLP/VOA |
| Acrylonitrile | 107.13.1 | CLP/VOA |
| Allyl Alcohol | 107.18.6 | NRA |
| 4-Aminobiphenyl | 92.67.1 | CLP/BNA |
| Aramite | 140.57.8 | CLP/BNA |
| Benzenethiol | 108.98.5 | CLP/BNA |
| p-Benzoquinone | 106.51.4 | CLP/BNA |
| Bromoacetone | 598.31.2 | NRA |
| 2-sec-butyl-4,6-dinitrophenol | 88.85.7 | CLP/BNA |
| Chlorobenzilate | 510.15.6 | CLP/BNA |
| 2-chloro-1,3-butadiene | 126.99.8 | CLP/BNA |
| 3-chloropropene | 107.05.1 | CLP/VOA |
| 3-chloropropionitrile | 542.76.7 | CLP/BNA |
| Diallate | 2303.16.4 | CLP/BNA |
| Dibenzo [a,e] pyrene | 192.65.4 | CLP/BNA |
| Dibenzo [a,h] pyrene | 189.64.0 | CLP/BNA |
| Dibenzo [a,i] pyrene | 189.55.9 | CLP/BNA |
| 1,2-dibromo-3-chloropropane | 96.12.8 | CLP/VOA |
| 1,2-dibromoethane | 106.93.4 | CLP/VOA |
| Dibromomethane | 74.95.3 | CLP/VOA |
| 1,4-dichloro-2-butene | 764.41.0 | CLP/VOA |
| Dichlorodifluoromethane | 75.71.8 | CLP/VOA |
| 2,6 Dichlorophenol | 87.65.0 | CLP/BNA |
| 1,3-Dichloropronene | 542.75.6 | CLP/VOA |
| 0,0-Diethyl 0-2-pyrazinyl phosphorothioate | 297.97.2 | NRA |
| 3,3-Dimethoxybenzidine | 119.90.4 | CLP/BNA |
| p-Dimethylaminozobenzene | 60.11.7 | CLP/BNA |
| 7,12-Dimethylbenz[a]anthracene | 57.97.6 | CLP/BNA |
| 3,3$^1$-Dimethylbenzidine | 119.93.7 | CLP/BNA |
| alpha-Dimethylphenethylamine | 122.09.8 | CLP/BNA |
| 1,4-Dioxane | 123.91.1 | NRA |
| Diphenylamine | 122.39.4 | CLP/BNA |
| 1,2-Diphenylhydrazine | 122.66.7 | CLP/BNA |
| Di-n-propylnitrosamine | 621.64.7 | CLP/BNA |
| Disulfoton | 298.04.4 | CLP/VOA |
| Ethyl Cyanide | 107.12.0 | CLP/VOA |
| Ethylene Oxide | 75.21.8 | NRA |
| meta-dinitrobenzene | 100.25.4 | CLP/BNA |
| Silvex | 93.72.1 | NRA |
| 1,2,3-trichloropronene | 96.18.4 | CLP/VOA |
| Tris (2,3-dibromopropyl) phosphate | 126.72.7 | CLP/BNA |

| Common Name | CAS RN | Class[a] |
|---|---|---|
| Phenacetin | 62.44.2 | CLP/BNA |
| N-Phenylthiourea | 103.85.5 | CLP/BNA |
| Phorate | 298.02.2 | NRA |
| Famphur | 52.85.7 | NRA |
| 2-Picoline | 109.06.8 | CLP/BNA |
| Propanamide | 23950.58.5 | CLP/BNA |
| 2-Propyn-1-ol | 107.19.7 | NRA |
| Pyridine | 110.86.1 | CLP/BNA |
| Resorcinol | 108.46.3 | CLP/BNA |
| Safrole | 44.59.7 | CLP/BNA |
| 1,2,4,5-Tetrachlorobenzene | 95.94.3 | CLP/BNA |
| 1,1,1,2-Tetrachloroethane | 630.20.6 | CLP/VOA |
| 2-Naphthylamine | 91.59.8 | CLP/BNA |
| N-Nitrosodi-n-butylamine | 924.16.3 | CLP/BNA |
| N-Nitrosodiethylamine | 55.18.5 | CLP/BNA |
| N-Nitrosomethylethylamine | 10595.95.6 | CLP/BNA |
| N-Nitrosomorpholine | 59.89.2 | CLP/BNA |
| N-Nitrosopiperdine | 100.75.4 | CLP/BNA |
| 5-Nitro-o-toluidine | 99.44.8 | CLP/BNA |
| Parathion | 56.38.2 | NRA |
| Pentachlorobenzene | 608.93.5 | CLP/BNA |
| Pentachloroethane | 76.01.7 | CLP/BNA |
| Pentachloronitrobenzene | 82.68.8 | CLP/BNA |
| Kepone | 143.50.0 | CLP/PCB-Pest |
| Malonitrile | 109.77.3 | CLP/BNA |
| Methyacrylonitrile | 126.98.7 | CLP/VOA |
| Methapyrilene | 91.80.5 | CLP/BNA |
| 3-Methylchloranthrene | 56.49.5 | CLP/BNA |
| 4,4-Methylene-bis (2-chloroaniline) | 101.14.4 | CLP/BNA |
| Methylmethacrylate | 80.62.6 | CLP/BNA |
| Methylmethanesulfonate | 66.27.3 | CLP/BNA |
| Aldicarb | 116.06.3 | CLP/BNA |
| Methyl parathion | 298.00.0 | NRA |
| 1,4 Naphthoquinone | 130.15.4 | CLP/BNA |
| 1-Naphthylamine | 134.32.7 | CLP/BNA |
| 2,3,4,6-Tetrachlorophenol | 58.90.2 | CLP/BNA |
| Tetraethyldithiopyrophosphate | 3689.24.5 | NRA |
| Trichloromethanethal | 75.70.7 | CLP/BNA |
| Trichloromonofluoromethane | 75.69.4 | CLP/VOA |
| 2,4,5-T | 93.76.5 | NRA |
| Ethyl Methacrylate | 97.63.2 | CLP/BNA |
| Isodrin | 465.73.6 | CLP/PCB-Pest |
| Hexachlorophene | 70.30.4 | CLP/BNA |
| Hexachloropropene | 1888.71.7 | CLP/VOA |
| Iodomethane | 74.88.4 | CLP/VOA |
| Isobutylalcohol | 78.33.1 | CLP/VOA |
| Isosafrole | 120.58.1 | NRA |

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NOTES

[a] Class Abbreviations

NRA - Not readily analyzable using current CLP Procedures

CLP/VOA - Potentially analyzable using current CLP/HSL GC/MS Volatile Organics Procedure

CLP/BNA - Potentially analyzable using current CLP/HSL Base/Neutral Acid Extractable GC/MS Procedure

CLP/PCB-Pest - Potentially analyzable using current CLP/HSL PCB/Pesticide GC Procedure

# ORGANIC COMPOUNDS ON MODIFIED
# APPENDIX VIII
# LIST THAT ARE NOT READILY ANALYZABLE BY CURRENT
# CLP/HSL PROCEDURES

| Common Name | CAS RN | Class[a] |
|---|---|---|
| Allyl alcohol | 107.18.6 | WS/NV |
| Bromoacetone | 598.31.2 | WR |
| 0,0-Diethyl-0-2-Pyrazinyl phosphorothioate | 297.97.2 | OP |
| 1,4 Dioxane | 123.91.1 | WS/NV |
| Ethylene Oxide | 75.21.8 | NR (VOA) |
| Silvex | 93.72.1 | CH |
| Phorate | 298.02.2 | OP |
| Famphur | 52.85.7 | OP |
| 2-Propyn-1-ol | 107.19.7 | WS/NV |
| Parathion | 56.38.2 | OP |
| Methyl Parathion | 298.00.0 | OP |
| Tetraethyldithiopyrophosphate | 3689.24.5 | WR |
| 2,4,5-T | 93.76.5 | CH |
| Isosafrole | 120.58.1 | D/H |

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NOTES

[a] Class Abbreviations

WS/NV - Water soluble, nonvolatile compound probability not amenable to purge and trap or liquid/liquid extraction pretreatment.

WR - Water reactive, unanalyzable in aqueous matrix.

OP - Organophosphorous pesticide best analyzed by a modified SW-846, Method 8140.

NR (VOA) - Not recoverable at 200 PPB using standard HSL/CLP volatile organics procedures. May be more ameneable to head space analysis.

CH - Chlorinate herbicide, must be derivatized prior to analysis. Best analyzed using modified SW-846 Method 8150.

D/H - Decomposes at conventional GC temperatures HLPC procedure may be applicable.

## CLP VOLATILE ORGANIC CRDL

| Target compound name | SPCC[b]<br>CCC[c] | Low soil CRDL, µg/kg | Low water CRDL, µg/L | CAS number |
|---|---|---|---|---|
| Chloromethane | SPCC | 10 | 10 | 74-87-3 |
| Bromomethane | | 10 | 10 | 74-83-9 |
| Vinyl Chloride | CCC | 10 | 10 | 75-01-4 |
| Chloroethane | | 10 | 10 | 75-00-3 |
| Methylene Chloride | | 5 | 5 | 75-09-2 |
| Acetone | | 10 | 10 | 67-64-1 |
| Carbon Disulfide | | 5 | 5 | 75-15-0 |
| 1,1-Dichloroethene | CCC | 5 | 5 | 75-35-4 |
| 1,1-Dichloroethane | SPCC | 5 | 5 | 75-35-3 |
| Trans-1,2-Dichloroethene | | 5 | 5 | 156-60-5 |
| Chloroform | CCC | 5 | 5 | 67-66-3 |
| 1,2-Dichloroethane | | 5 | 5 | 107-06-2 |
| 2-Butanone | | 10 | 10 | 78-93-3 |
| 1,1,1-Trichloroethane | | 5 | 5 | 71-55-6 |
| Carbon Tetrachloride | | 5 | 5 | 56-23-5 |
| Vinyl Acetate | | 10 | 10 | 108-05-4 |
| Bromodichloromethane | | 5 | 5 | 75-27-4 |
| 1,1,2,2-Tetrachloroethane | SPCC | 5 | 5 | 79-34-5 |
| 1,2-Dichloropropane | CCC | 5 | 5 | 78-87-5 |
| Trans-1,3-Dichloropropene | | 5 | 5 | 10061-02-6 |
| Trichloroethene | | 5 | 5 | 79-01-6 |
| Dibromochloromethane | | 5 | 5 | 124-48-1 |
| 1,1,2-Trichloroethane | | 5 | 5 | 79-00-5 |
| Benzene | | 5 | 5 | 71-43-2 |
| Cis-1,3-Dichloropropene | | 5 | 5 | 10061-01-5 |
| 2-Chloroethyl Vinyl Ether | | 10 | 10 | 110-75-8 |
| Bromoform | SPCC | 5 | 5 | 75-25-2 |
| 4-Methyl-2-pentanone | | 10 | 10 | 108-10-1 |
| 2-Hexanone | | 10 | 10 | 591-78-6 |
| Tetrachloroethene | | 5 | 5 | 127-18-4 |
| Toluene | CCC | 5 | 5 | 108-88-3 |
| Chlorobenzene | SPCC | 5 | 5 | 108-90-7 |
| Ethyl Benzene | CCC | 5 | 5 | 100-41-4 |
| Styrene | | 5 | 5 | 100-42-5 |
| Total Xylenes | | 5 | 5 | N.A. |

[a] CRDL values obtained from the IFB WA85-J664 [7].

[b] System Performance Check Compounds (SPCC) are used to check compound instability and degradation in the GC/MS and to insure minimum average response factors are met prior to the use of the calibration curve.

[c] Column Check Compounds (CCC) are used to check the validity of the initial calibration.

Note: Medium soil and water CRDLs are 100 times the low level CRDLs.

SOURCE: Flotard, R.D. et al 1986

# CLP INORGANIC COMPOUND CRDL, INSTRUMENT DETECTION LEVEL AND WAVELENGTH

| Element | CRDL | Method | N | IDL Mean | IDL Std Dev | Wave-Length (nm) |
|---|---|---|---|---|---|---|
| Al | 200 | ICP | 7 | 70.7 | 59.3 | 309.3 |
| Sb | 60 | ICP | 5 | 42.3 | 11.3 | 217.6 |
| As | 10 | FAA | 18 | 4.6 | 2.3 | 198.7 |
| Ba | 200 | ICP | 5 | 22.1 | 31.7 | 493.4 |
| Be | 5 | ICP | 10 | 2.3 | 1.7 | 312.0 |
| Cd | 5 | ICP | 5 | 4.0 | 1.1 | 228.8 |
| Ca | 5000 | ICP | 7 | 529 | 472 | 317.9 |
| Cr | 10 | ICP | 9 | 5.8 | 2.9 | 267.7 |
| Co | 50 | ICP | 11 | 11.4 | 8.5 | 228.6 |
| Cu | 25 | ICP | 11 | 9.7 | 6.5 | 324.5 |
| Fe | 100 | ICP | 10 | 27.4 | 20.9 | 259.9 |
| Pb | 5 | ICP | 12 | 2.3 | 1.2 | 283.3 |
| Mg | 5000 | ICP | 11 | 385 | 449 | 279.6 |
| Mn | 15 | ICP | 10 | 5.2 | 4.6 | 257.6 |
| Hg | 0.2 | CV | 12 | 0.2 | 0.1 | 253.7 |
| Ni | 40 | ICP | 9 | 17.8 | 10.1 | 232.0 |
| K | 5000 | ICP | 8 | 668 | 444 | 766.5 |
| Se | 5 | FAA | 18 | 2.8 | 1.3 | 196.0 |
| Ag | 10 | ICP | 10 | 5.4 | 2.7 | 328.1 |
| Na | 5000 | ICP | 9 | 756 | 864 | 589.0 |
| Tl | 10 | ICP | 18 | 4.3 | 2.4 | 276.8 |
| Sn | 40 | ICP | 7 | 23.8 | 8.4 | 190.0 |
| V | 50 | ICP | 10 | 13.1 | 10.0 | 292.5 |
| Zn | 20 | ICP | 0 | 8.3 | 6.3 | 213.9 |

IDL - Instrument Detection Limit (μg/L).
N - Number of laboratories using the most common wavelength.
CRDL - Contract Required Detection Limit (μg/L).

SOURCE: Aleckson, K.A. et al 1986.

## CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL

| Compound name | SPCC[a] or CCC[b] | Low Soil CRDL, µg/kg | Low Water CRDL, µg/L | CAS Number |
|---|---|---|---|---|
| Phenol | CCC | 330 | 10 | 108-95-2 |
| bis(2-Chloroethyl)ether | | 330 | 10 | 111-44-4 |
| 2-Chlorophenol | | 330 | 10 | 95-57-8 |
| 1,3-Dichlorobenzene | | 330 | 10 | 541-73-1 |
| 1,4-Dichlorobenzene | CCC | 330 | 10 | 106-46-7 |
| Benzyl alcohol | | 330 | 10 | 100-51-6 |
| 1,2-Dichlorobenzene | | 330 | 10 | 95-50-1 |
| 2-Methylphenol | | 330 | 10 | 95-48-7 |
| bis(2-Chloroisopropyl)ether | | 330 | 10 | 39638-32-9 |
| 4-Methylphenol | | 330 | 10 | 106-44-5 |
| N-Nitroso-di-n-propylamine | SPCC | 330 | 10 | 621-64-7 |
| Hexachloroethane | | 330 | 10 | 67-72-1 |
| Nitrobenzene | | 330 | 10 | 98-95-3 |
| Isophorone | | 330 | 10 | 78-59-1 |
| 2-Nitrophenol | CCC | 330 | 10 | 88-75-5 |
| 2,4-Dimethylphenol | | 330 | 10 | 105-67-9 |
| Benzoic acid | | 1,600 | 50 | 65-85-0 |
| bis(2-Chloroethoxy)methane | | 330 | 10 | 111-91-1 |
| 2,4-Dichlorophenol | | 330 | 10 | 120-83-2 |
| 1,2,4-Trichlorobenzene | | 330 | 10 | 120-82-1 |
| Naphthalene | | 330 | 10 | 91-20-3 |
| 4-Chloroaniline | | 330 | 10 | 106-47-8 |
| Hexachlorobutadiene | CCC | 330 | 10 | 87-68-3 |
| 4-Chloro-3-methylphenol | CCC | 330 | 10 | 59-50-7 |
| 2-Methylnaphthalene | | 330 | 10 | 91-57-6 |
| Hexachlorocyclopentadiene | SPCC | 330 | 10 | 77-47-4 |
| 2,4,6-Trichlorophenol | CCC | 330 | 10 | 88-06-2 |
| 2,4,5-Trichlorophenol | | 1,600 | 50 | 95-95-4 |
| 2-Chloronaphthalene | | 330 | 10 | 91-58-7 |
| 2-Nitroaniline | | 1,600 | 50 | 88-74-4 |
| Dimethylphthalate | | 330 | 10 | 131-11-3 |
| Acenaphthylene | | 330 | 10 | 208-96-8 |
| 3-Nitroaniline | | 1,600 | 50 | 99-09-2 |
| Acenaphthene | CCC | 330 | 10 | 83-32-9 |
| 2,4-Dinitrophenol | SPCC | 1,600 | 50 | 51-28-5 |
| 4-Nitrophenol | SPCC | 1,600 | 50 | 100-02-7 |
| Dibenzofuran | | 330 | 10 | 132-64-9 |
| 2,4-Dinitrotoluene | | 330 | 10 | 121-14-2 |
| 2,6-Dinitrotoluene | | 330 | 10 | 606-20-2 |
| Diethylphthalate | | 330 | 10 | 84-66-2 |
| 4-Chlorophenyl-phenylether | | 330 | 10 | 7005-72-3 |
| Fluorene | | 330 | 10 | 86-73-7 |
| 4-Nitroaniline | | 1,600 | 50 | 100-01-6 |
| 4,6-Dinitro-2-methylphenol | | 1,600 | 50 | 534-52-1 |

## CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL
(continued)

| Compound name | SPCC[a] or CCC[b] | Low Soil CRDL, µg/kg | Low Water CRDL, µg/L | CAS Number |
|---|---|---|---|---|
| N-Nitrosodiphenylamine | CCC | 330 | 10 | 86-30-6 |
| 4-Bromophenyl-phenylether |  | 330 | 10 | 101-55-3 |
| Hexachlorobenzene |  | 330 | 10 | 118-74-1 |
| Pentachlorophenol | CCC | 1,600 | 50 | 87-86-5 |
| Phenanthrene |  | 330 | 10 | 85-01-8 |
| Anthracene |  | 330 | 10 | 120-12-7 |
| Di-n-butylphthalate |  | 330 | 10 | 84-74-2 |
| Fluoranthene | CCC | 330 | 10 | 206-44-0 |
| Pyrene |  | 330 | 10 | 129-00-0 |
| Butylbenzylphthalate |  | 330 | 10 | 85-68-7 |
| 3,3'-Dichlorobenzidine |  | 660 | 20 | 91-94-1 |
| Benzo(a)anthracene |  | 330 | 10 | 56-55-3 |
| bis(2-Ethylhexyl)phthalate |  | 330 | 10 | 117-81-7 |
| Chrysene |  | 330 | 10 | 218-01-9 |
| Di-n-octylphthalate | CCC | 330 | 10 | 117-84-0 |
| Benzo(b)fluoranthene |  | 330 | 10 | 205-99-2 |
| Benzo(k)fluoranthene |  | 330 | 10 | 207-08-9 |
| Benzo(a)pyrene | CCC | 330 | 10 | 50-32-8 |
| Indeno(1,2,3-cd)pyrene |  | 330 | 10 | 193-39-5 |
| Dibenz(a,h)anthracene |  | 330 | 10 | 53-70-3 |
| Benzo(g,h,i)perylene |  | 330 | 10 | 191-24-2 |

[a] CCC-Calibration Check Compound

[b] SPCC-System Performance Check Compound

Note: Medium soil/sediment contract required detection limits are 60 times the individual low soil/sediment CRDL and medium water contract required detection limits are 100 times the individual low water CRDL.

SOURCE: Wolf, J.S. et al 1986.

# APPENDIX H

# CONTRACT REQUIRED DETECTION LIMITS FOR HSL ANALYSES USING CLP IFB PROCEDURES

# CLP VOLATILE ORGANIC CRDL

| Target compound name | SPCC[b]<br>CCC[c] | Low soil CRDL, µg/kg | Low water CRDL, µg/L | CAS number |
|---|---|---|---|---|
| Chloromethane | SPCC | 10 | 10 | 74-87-3 |
| Bromomethane | | 10 | 10 | 74-83-9 |
| Vinyl Chloride | CCC | 10 | 10 | 75-01-4 |
| Chloroethane | | 10 | 10 | 75-00-3 |
| Methylene Chloride | | 5 | 5 | 75-09-2 |
| Acetone | | 10 | 10 | 67-64-1 |
| Carbon Disulfide | | 5 | 5 | 75-15-0 |
| 1,1-Dichloroethene | CCC | 5 | 5 | 75-35-4 |
| 1,1-Dichloroethane | SPCC | 5 | 5 | 75-35-3 |
| Trans-1,2-Dichloroethene | | 5 | 5 | 156-60-5 |
| Chloroform | CCC | 5 | 5 | 67-66-3 |
| 1,2-Dichloroethane | | 5 | 5 | 107-06-2 |
| 2-Butanone | | 10 | 10 | 78-93-3 |
| 1,1,1-Trichloroethane | | 5 | 5 | 71-55-6 |
| Carbon Tetrachloride | | 5 | 5 | 56-23-5 |
| Vinyl Acetate | | 10 | 10 | 108-05-4 |
| Bromodichloromethane | | 5 | 5 | 75-27-4 |
| 1,1,2,2-Tetrachloroethane | SPCC | 5 | 5 | 79-34-5 |
| 1,2-Dichloropropane | CCC | 5 | 5 | 78-87-5 |
| Trans-1,3-Dichloropropene | | 5 | 5 | 10061-02-6 |
| Trichloroethene | | 5 | 5 | 79-01-6 |
| Dibromochloromethane | | 5 | 5 | 124-48-1 |
| 1,1,2-Trichloroethane | | 5 | 5 | 79-00-5 |
| Benzene | | 5 | 5 | 71-43-2 |
| Cis-1,3-Dichloropropene | | 5 | 5 | 10061-01-5 |
| 2-Chloroethyl Vinyl Ether | | 10 | 10 | 110-75-8 |
| Bromoform | SPCC | 5 | 5 | 75-25-2 |
| 4-Methyl-2-pentanone | | 10 | 10 | 108-10-1 |
| 2-Hexanone | | 10 | 10 | 591-78-6 |
| Tetrachloroethene | | 5 | 5 | 127-18-4 |
| Toluene | CCC | 5 | 5 | 108-88-3 |
| Chlorobenzene | SPCC | 5 | 5 | 108-90-7 |
| Ethyl Benzene | CCC | 5 | 5 | 100-41-4 |
| Styrene | | 5 | 5 | 100-42-5 |
| Total Xylenes | | 5 | 5 | N.A. |

[a] CRDL values obtained from the IFB WA85-J664 [7].

[b] System Performance Check Compounds (SPCC) are used to check compound instability and degradation in the GC/MS and to insure minimum average response factors are met prior to the use of the calibration curve.

[c] Column Check Compounds (CCC) are used to check the validity of the initial calibration.

Note: Medium soil and water CRDLs are 100 times the low level CRDLs.

SOURCE: Flotard, R.D. et al 1986

# CLP INORGANIC COMPOUND CRDL,
# INSTRUMENT DETECTION LEVEL AND WAVELENGTH

| Element | CRDL | Method | N | IDL Mean | IDL Std Dev | Wave-Length (nm) |
|---|---|---|---|---|---|---|
| Al | 200 | ICP | 7 | 70.7 | 59.3 | 309.3 |
| Sb | 60 | ICP | 5 | 42.3 | 11.3 | 217.6 |
| As | 10 | FAA | 18 | 4.6 | 2.3 | 198.7 |
| Ba | 200 | ICP | 5 | 22.1 | 31.7 | 493.4 |
| Be | 5 | ICP | 10 | 2.3 | 1.7 | 312.0 |
| Cd | 5 | ICP | 5 | 4.0 | 1.1 | 228.8 |
| Ca | 5000 | ICP | 7 | 529 | 472 | 317.9 |
| Cr | 10 | ICP | 9 | 5.8 | 2.9 | 267.7 |
| Co | 50 | ICP | 11 | 11.4 | 8.5 | 228.6 |
| Cu | 25 | ICP | 11 | 9.7 | 6.5 | 324.5 |
| Fe | 100 | ICP | 10 | 27.4 | 20.9 | 259.9 |
| Pb | 5 | ICP | 12 | 2.3 | 1.2 | 283.3 |
| Mg | 5000 | ICP | 11 | 385 | 449 | 279.6 |
| Mn | 15 | ICP | 10 | 5.2 | 4.6 | 257.6 |
| Hg | 0.2 | CV | 12 | 0.2 | 0.1 | 253.7 |
| Ni | 40 | ICP | 9 | 17.8 | 10.1 | 232.0 |
| K | 5000 | ICP | 8 | 668 | 444 | 766.5 |
| Se | 5 | FAA | 18 | 2.8 | 1.3 | 196.0 |
| Ag | 10 | ICP | 10 | 5.4 | 2.7 | 328.1 |
| Na | 5000 | ICP | 9 | 756 | 864 | 589.0 |
| Tl | 10 | ICP | 18 | 4.3 | 2.4 | 276.8 |
| Sn | 40 | ICP | 7 | 23.8 | 8.4 | 190.0 |
| V | 50 | ICP | 10 | 13.1 | 10.0 | 292.5 |
| Zn | 20 | ICP | 0 | 8.3 | 6.3 | 213.9 |

IDL - Instrument Detection Limit (μg/L).
N - Number of laboratories using the most common wavelength.
CRDL - Contract Required Detection Limit (μg/L).

SOURCE: Aleckson, K.A. et al 1986.

# CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL

| Compound name | SPCC[a] or CCC[b] | Low Soil CRDL, µg/kg | Low Water CRDL, µg/L | CAS Number |
|---|---|---|---|---|
| Phenol | CCC | 330 | 10 | 108-95-2 |
| bis(2-Chloroethyl)ether | | 330 | 10 | 111-44-4 |
| 2-Chlorophenol | | 330 | 10 | 95-57-8 |
| 1,3-Dichlorobenzene | | 330 | 10 | 541-73-1 |
| 1,4-Dichlorobenzene | CCC | 330 | 10 | 106-46-7 |
| Benzyl alcohol | | 330 | 10 | 100-51-6 |
| 1,2-Dichlorobenzene | | 330 | 10 | 95-50-1 |
| 2-Methylphenol | | 330 | 10 | 95-48-7 |
| bis(2-Chloroisopropyl)ether | | 330 | 10 | 39638-32-9 |
| 4-Methylphenol | | 330 | 10 | 106-44-5 |
| N-Nitroso-di-n-propylamine | SPCC | 330 | 10 | 621-64-7 |
| Hexachloroethane | | 330 | 10 | 67-72-1 |
| Nitrobenzene | | 330 | 10 | 98-95-3 |
| Isophorone | | 330 | 10 | 78-59-1 |
| 2-Nitrophenol | CCC | 330 | 10 | 88-75-5 |
| 2,4-Dimethylphenol | | 330 | 10 | 105-67-9 |
| Benzoic acid | | 1,600 | 50 | 65-85-0 |
| bis(2-Chloroethoxy)methane | | 330 | 10 | 111-91-1 |
| 2,4-Dichlorophenol | | 330 | 10 | 120-83-2 |
| 1,2,4-Trichlorobenzene | | 330 | 10 | 120-82-1 |
| Naphthalene | | 330 | 10 | 91-20-3 |
| 4-Chloroaniline | | 330 | 10 | 106-47-8 |
| Hexachlorobutadiene | CCC | 330 | 10 | 87-68-3 |
| 4-Chloro-3-methylphenol | CCC | 330 | 10 | 59-50-7 |
| 2-Methylnaphthalene | | 330 | 10 | 91-57-6 |
| Hexachlorocyclopentadiene | SPCC | 330 | 10 | 77-47-4 |
| 2,4,6-Trichlorophenol | CCC | 330 | 10 | 88-06-2 |
| 2,4,5-Trichlorophenol | | 1,600 | 50 | 95-95-4 |
| 2-Chloronaphthalene | | 330 | 10 | 91-58-7 |
| 2-Nitroaniline | | 1,600 | 50 | 88-74-4 |
| Dimethylphthalate | | 330 | 10 | 131-11-3 |
| Acenaphthylene | | 330 | 10 | 208-96-8 |
| 3-Nitroaniline | | 1,600 | 50 | 99-09-2 |
| Acenaphthene | CCC | 330 | 10 | 83-32-9 |
| 2,4-Dinitrophenol | SPCC | 1,600 | 50 | 51-28-5 |
| 4-Nitrophenol | SPCC | 1,600 | 50 | 100-02-7 |
| Dibenzofuran | | 330 | 10 | 132-64-9 |
| 2,4-Dinitrotoluene | | 330 | 10 | 121-14-2 |
| 2,6-Dinitrotoluene | | 330 | 10 | 606-20-2 |
| Diethylphthalate | | 330 | 10 | 84-66-2 |
| 4-Chlorophenyl-phenylether | | 330 | 10 | 7005-72-3 |
| Fluorene | | 330 | 10 | 86-73-7 |
| 4-Nitroaniline | | 1,600 | 50 | 100-01-6 |
| 4,6-Dinitro-2-methylphenol | | 1,600 | 50 | 534-52-1 |

## CLP SEMI-VOLATILE HSL COMPOUNDS AND CRDL
(continued)

| Compound name | SPCC[a] or CCC[b] | Low Soil CRDL, µg/kg | Low Water CRDL, µg/L | CAS Number |
|---|---|---|---|---|
| N-Nitrosodiphenylamine | CCC | 330 | 10 | 86-30-6 |
| 4-Bromophenyl-phenylether | | 330 | 10 | 101-55-3 |
| Hexachlorobenzene | | 330 | 10 | 118-74-1 |
| Pentachlorophenol | CCC | 1,600 | 50 | 87-86-5 |
| Phenanthrene | | 330 | 10 | 85-01-8 |
| Anthracene | | 330 | 10 | 120-12-7 |
| Di-n-butylphthalate | | 330 | 10 | 84-74-2 |
| Fluoranthene | CCC | 330 | 10 | 206-44-0 |
| Pyrene | | 330 | 10 | 129-00-0 |
| Butylbenzylphthalate | | 330 | 10 | 85-68-7 |
| 3,3'-Dichlorobenzidine | | 660 | 20 | 91-94-1 |
| Benzo(a)anthracene | | 330 | 10 | 56-55-3 |
| bis(2-Ethylhexyl)phthalate | | 330 | 10 | 117-81-7 |
| Chrysene | | 330 | 10 | 218-01-9 |
| Di-n-octylphthalate | CCC | 330 | 10 | 117-84-0 |
| Benzo(b)fluoranthene | | 330 | 10 | 205-99-2 |
| Benzo(k)fluoranthene | | 330 | 10 | 207-08-9 |
| Benzo(a)pyrene | CCC | 330 | 10 | 50-32-8 |
| Indeno(1,2,3-cd)pyrene | | 330 | 10 | 193-39-5 |
| Dibenz(a,h)anthracene | | 330 | 10 | 53-70-3 |
| Benzo(g,h,i)perylene | | 330 | 10 | 191-24-2 |

[a] CCC-Calibration Check Compound

[b] SPCC-System Performance Check Compound

Note: Medium soil/sediment contract required detection limits are 60 times the individual low soil/sediment CRDL and medium water contract required detection limits are 100 times the individual low water CRDL.

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SOURCE: Wolf, J.S. et al 1986.